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ABSTRACT

The joint hearings which are documented in these proceedings were held to enhance the awareness of the Congress, the executive branch, and the private and public sectors of both the potential educational benefits of new information and telecommunications technologies, and the possible social and economic impacts resulting from the widespread use of these technologies in the educational process. A variety of perspectives on these two issues was presented during the two days of sessions. Among the witnesses who appeared before the subcommittees were representatives from the National Institute of Education, the World Institute for Computer Assisted Teaching, Massachusetts Institute of Technology, the Corporation for Public Broadcasting, the Warner Cable Corporation, and the Educational Testing Service. In addition to these presentations, six workshops were held which focused on the implications of instructional technology for elementary secondary education, postsecondary education, public planning, special education, adult education, and information technology development. The recommendations presented to Congress by the workshop participants are included in this document. (LLS)

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INFORMATION TECHNOLOGY IN EDUCATION

U.S. DEPARTMENT OF HEALTH,
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JOINT HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY

AND THE

SUBCOMMITTEE ON SELECT EDUCATION

OF THE

COMMITTEE ON EDUCATION AND LABOR
HOUSE OF REPRESENTATIVES

NINETY-SIXTH CONGRESS

SECOND SESSION

APRIL 2, 3, 1980

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INFORMATION TECHNOLOGY IN EDUCATION

WEDNESDAY, APRIL 2, 1980

U.S. HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY AND THE COMMITTEE ON EDUCATION AND LABOR, SUBCOMMITTEE ON SELECT EDUCATION,

Washington, D.C.

The subcommittees met, pursuant to notice, at 9:15 a.m., in room 2318, Rayburn House Office Building, Hon. George E. Brown, Jr., chairman of the Subcommittee on Science, Research and Technology, presiding.

Mr. BROWN. This extravaganza will get underway.

We are embarked upon a rather unique proceeding for the House of Representatives this morning. Formally, this is a joint hearing of two subcommittees, one of the Science and Technology Committee and one of the Education and Labor Committee. Actually it is a part of a much broader exercise than that, aimed at focusing on and utilizing, to some degree, the new technologies and communications, computing and related fields, and getting as much input from the participants as we can.

Now, before I make a short opening statement, I would like to make an announcement. We have, as you know, available an interpreter for the hearing disabled. We have reserved seats in the front row for any who may have a hearing disability. We would like to invite any such persons to come up if it would be convenient for them. Otherwise, we will allow these seats to be filled by the audience who have no particular claim to fame, other than that they want to be closer to the chairman.

I will first make a brief statement and turn to our distinguished cochairman, the chairman of the Education Committee, for an opening statement, and he will introduce our first witness at that time.

I am pleased to open this seminar on information technology in education with these important hearings. We welcome the entire audience, and we express special appreciation to those of you who are participating in the workshop and demonstration portions of this seminar.

The objectives of the seminar are to enhance the awareness of the Congress, the executive branch, and the private and public sectors of the potential educational benefits of new information and telecommunications technologies, and, second, the possible social and economic impacts resulting from the widespread use of these technologies in the educational process. The potential for information and telecommunications technologies is clearly evident. The best means of utilizing and planning for the use of these technologies to achieve educational objectives is less obvious. Science and technology, like most other human activities, are capable of generating both good and bad consequences. I should underline that. The challenge before us is to apply or to develop expertise which will maximize the positive impacts of these technologies in all educational environments. That means the school, the workplace, and the home. Such expertise is not limited to scientific and technical knowledge, but it includes planning and evaluation processes to establish policies and implementation programs for achieving societal goals and shaping the tools and techniques necessary to achieve broad national goals.

If public policies are to be responsive to the needs of our "information society," we must develop mechanisms and institutions with the flexibility to adopt technological change and to cope in a humane and equitable way with the increasingly interdisciplinary nature of scientific research and new knowledge. The time is long overdue for the Congress to address information and related technologies as a national resource.

We must rely on the experts such as those of you participating in this seminar, to derive a consensus which will direct us toward the appropriate goals and policies. The seminar participants represent a wide variety of interests and organizations. It is important that individual perspectives are exchanged in this seminar and beyond to devise priorities necessary to achieve educational objectives rather than to develop priorities based on the attributes of a single technology or single interest. We look forward to the expertise and perspectives of the seminar participants and our witnesses this morning.

At this time I would like to introduce my very distinguished colleague, Congressman Carl Perkins of Kentucky, who is chairman of the Committee on Education and Labor, whose Subcommittee on Select Education is cosponsoring this seminar.

Mr. PERKINS. Thank you very much, Mr. Chairman.

First, I want to state that we are very fortunate to have Congressman Brown conducting these hearings because there is not a more dedicated chairman or a more persevering or conscientious chairman in the House of Representatives than Congressman Brown. I make that statement because when he first came to the Congress, he served on the Education and Labor Committee. He decided to go out to a better committee.

Mr. BROWN. I am still working on education.

Mr. PERKINS. His production and his contributions have been tremendous during his tenure in the U.S. Congress.

The Subcommittee on Select Education is pleased to join with the Subcommittee on Science, Research and Technology for a joint hearing on the subject of information technology in education. This is the first time that the Education and Labor Committee and the Science and Technology Committee have joined together to explore this issue. I believe that we have gathered together in this seminar some of the finest minds in the country, and we are looking forward to the testimony and the final recommendations of the working groups.

Mr. Simon, the chairman of the Subcommittee on Select Education, regrets that he cannot be present for these hearings. He has been carrying out his duties for the past several weeks in spite of a case of walking pneumonia. His physician and his wife have finally ordered a week of rest, and Mr. Simon has reluctantly complied. He sends you his regards and wishes he could be present. I believe that Mr. Miller will be substituting as chairman for the rest of the hearing.

The subcommittees have decided to sponsor this hearing because it is time that we reassess the revolution that is occurring in information technology and the likely impact of this revolution on our educational system. We believe that it is most appropriate to do this at a time when the creation of the Department of Education marks a new emphasis on education in this country.

Consequently, we are looking forward to your opinions on the Federal role in education technology, the efforts of the new technologies on teaching, learning, and our educational institutions. In a time of budget austerity, we are looking forward to your perspectives on the cost effectiveness and increased productivity of education programs as a result of the use of technology. It has been 10 years since the subject of the impact of information technology has been as thoroughly reviewed by Congress as planned by this joint hearing.

In 1970, the Commission on Instructional Technology reported to the Congress on specific actions which would provide for the most effective possible application of technology to American education. It is interesting to note that that report devoted more space to the use of audiovisual equipment, slides, filmstrips, tape recorders, and movie projectors, than to computer-assisted instruction.

Today many of you will discuss the impact of home computers on education, worldwide satellite hookups and other such equipment. We have come a long way in 10 years, but many of our schools, particularly those in rural areas, are still unable to afford adequate audiovisual equipment. I hope you will address in your discussions the questions and problems of equity involved in the use of access to the new technologies.

I would like to introduce to you the other members of the Education and Labor Committee. We have only one present, Congressman Erdahl, and he may wish to say something briefly.

Mr. **Erdahl**. Thank you very much, Mr. Chairman, and Chairman Brown. I want to say I am delighted to be here and more delighted to see so many of you here this morning.

We are embarked on an important cooperative task. We have members of our staffs in these two subcommittees and your expertise representing the public and private section as we are involved in this very important business of transmitting what seems to be an ever-increasing store of knowledge. I look forward to participating. I am here to learn and to listen.

Thank you, Mr. Chairman, for this opportunity to greet the group.

Mr. **Perkins**. Our first witness is Mr. Arthur S. Melmed. He is currently serving as the adviser to the Director of the National Institute of Education on the subject of technology and productivity.

He previously served with the National Science Foundation as head of the section for technological innovation and education. He has also served as past chairman of the educational panel, Committee on Automation Opportunities in the Service Sector, Federal Council for Science and Technology, and the Subcommittee for Educational Technology of the Federal Interagency Committee on Education.

Mr. Melmed, we are looking forward to hearing your testimony at this time. Please come around and go ahead.

Mr. **Brown**. Excuse me, Mr. Melmed.

May I explain to the audience that instead of the customary setup, the witnesses will speak at the podium. When they finish, they will sit here in the first row and they will be available for questioning by both the audience and the Members of Congress back here. This is a little unusual, but so is most of what we are doing in these 2 days. I think we can get used to it.

I am sorry for the interruption, Mr. Melmed.

STATEMENT OF ARTHUR S. MELMED, ADVISOR TO THE DIRECTOR, NATIONAL INSTITUTE OF EDUCATION

Mr. **Melmed**. Thank you very much, Mr. Chairman.

There are many applications in education of the new information processing and communication technologies based on the rapidly declining cost of storing and retrieving information, sending and receiving information, and transforming and reorganizing information in more or less complex ways. You will hear about and see some of these during the different sessions of this seminar. There are various categories of learners who may engage these and yet newer applications of the new technology now under development, and the Department of Education is concerned with all of these.

However, I am not going to attempt to paint a broad picture for you this morning. I have selected for my topic the role of the computer to improve learning in the elementary schools. It is in an arena in which we now have substantial working experience with which to anchor our vision of the future, and is of critical importance because it is concerned with children. I will not try to forecast the rate of acceptance of computers to improve learning in the schools, but I will identify some factors I think will affect use, and discuss some public policy and private sector investment opportunities.

I would like to start by dividing the factors affecting school use into two categories, which I call structural factors and school process factors. After some examples and a brief discussion of each, I will concentrate on the category of structural factors, or those factors that may affect school use which the schools are unable easily to influence, and do not. Some obvious structural factors are the acquisition cost of equipment, and the capacity and capability of equipment. There are also the maintenance cost of equipment, and the reliability of equipment. And finally, there is the availability and the cost of computer curriculums. I would like to note that I give very broad meaning to the use of the word "curriculums" and intend to include in the use of this word computer-assisted instruction (CAI), computer modeling, computer simulations, and so on.

It is clear, in a general way, that acquisition and maintenance costs are going down, while equipment capacity and reliability are going up. And these trends will continue for the foreseeable future. The picture is different and less clear in the matter of certain special capabilities, say, human speech recognition, and in the matter of computer curriculums. I will comment more fully on these matters later.

Now, among the school process factors which I believe may affect computer use in the schools, there are two that stand out in my mind. I will label one the activation energy and budget needed to overcome barriers to start-up and the other management factors and social process in the classroom. In the category of barriers to start-up, I include the budget process, and the locus of decisionmaking to get a new line item added to the school budget. The declining cost of equipment has the effect of reducing this barrier.

A second barrier to start-up is time and leadership. Various studies reveal that the time available to principals to play a leadership role to initiate new instructional undertakings is shrinking. Principals are concerned increasingly with various administrative tasks, and occasionally with school violence, and other things of the sort.

Finally, there is the cost of teacher training in the use of computers in the classroom. There does appear to exist at this time a growing interest in various quarters for new programs to maintain and develop new teacher competencies, including a program of teacher centers to be directed by the teachers themselves. There appears to be interest in the Congress also in the new Educational Professions Development Act. Perhaps the possibility of new budget to meet the cost of teacher training in the use of information technology in the classroom is becoming less remote.

Now, in the category of management factors and social process in the classroom, I will mention only the following. The label is actually surrogate for a larger number. If inadequate access time to computers and computer curriculums is available, by what criteria does the classroom teacher or the school system allocate this resource among the students? Is the computer resource located inside or outside the classroom? If outside, how does the teacher supervise this student activity? Also, whether the equipment is inside or outside, how does the teacher manage his or her time and that of the remaining students when only some are engaged in the use of this resource? And so on. These school factors are seemingly more difficult to disentangle in their effects on school use than the structural factors I identified previously. I mention in passing that the National Institute of Education is currently undertaking a program of research to improve our understanding of the relationship between this cluster of factors and school use of computers.

Some might argue, and do, that public policy could no doubt structure an incentive system to stimulate school use of computers, but there exists already a long menu to shape the allocation of any new public funds that may become available for education. So how can a priority allocation be asserted to meet the added cost for the use of computers in the schools to improve student learning? Perhaps by the use of effectiveness data which presumably affect the behaviors of policymakers and practitioners alike. So what effectiveness data to improve student learning do we have, and what can we infer from these data?

There are effectiveness data of different quantity and quality on various computer curriculums and on various applications of computers to improve learning in the schools. You will be learning more about many of these during different sessions of this seminar. But perhaps our best school use data from a narrow, technical point of view are based on that model of computer use known as "computer-assisted instruction" or "drill and practice," as opposed to other uses, such as computer modeling and computer simulations, and is based on some computer curriculums that were developed at Stanford University by Professor Suppes and his colleagues in the late 1960's and early 1970's.

Limited amounts of these data have been available suggesting a linear realtionship between improved achievement in elementary arithmetic and access time, or time on the terminal, to the elementary arithmetic computer curriculum for periods up to about a year; that is, within relatively narrow limits of up to about 10 minutes per student per school day, student achievement appeared to show improvement in proportion to time on terminal, beyond what might have otherwise been expected.

Obviously, even if true, this is not a phenomenon which can be expected to persist indefinitely, and is not a phenomenon which is entirely independent of other conditions of instruction such as classroom teaching, but as the amount of the Federal supplement for compensatory education for the individual student rose to meet the declining cost of computer-assisted instruction, the National Institute of Education in 1976 sponsored a 5-year longitudinal evaluation of these curriculums in several schools in the Los Angeles Unified School District. The study, now in its fourth full year, had several objectives.

One was to assess the effects of several years of computer-assisted instruction on student achievement in each of the three curriculums: elementary arithmetic, language arts, and basic reading skills. The second was to assess the effects of variations in the intensity of CAI on student achievement. And the third was to assess the effects of CAI in elementary arithmetic on the student's conceptual understanding of mathematical processes. The evaluation is being conducted by the Educational Testing Service of Princeton, N.J. Reports are available from them on the design and conduct of the study.

An analysis of the first 2 years of data is complete. A preliminary analysis of the third year's data has just recently become available. I would like to give you my rough-and-ready sense of the meaning of these results without various statistical qualifications that may technically be necessary.

Very briefly, the study includes mainly three experimental groups and two control groups made up of comparable youngsters attending schools eligible for Title 1 ESEA funds. The groups include youngsters from grades 1 through 6 eligible for compensatory instruction and randomly assigned among the experimental groups.

Some youngsters are assigned two 10-minute time periods per day on the elementary arithmetic computer curriculum, some 10 minutes, and some none. Youngsters in the experimental group assigned 10 minutes get an additional 10-minute time period on either of the other two computer curriculums, language arts or basic reading skills. Youngsters making up the third experimental group and not assigned any time on the elementary arithmetic computer curriculum are assigned 10-minute time periods on each of the other two. So all youngsters in the experimental groups are assigned a total of 20 minutes, while only some get 20 minutes of elementary arithmetic.

Two control groups are made up of youngsters not assigned any computer time: one for intraschool comparisons drawn from schools, housing the computer equipment used in the study; and the other for interschool comparisons made up of youngsters drawn from schools not housing any equipment.

My rough-and-ready analysis of the data is this. Youngsters receiving a 20-minute supplement in elementary arithmetic daily show achievement gains beyond what might otherwise have been expected on two separate test instruments, a curriculum specific test designed to match the strongly computational emphasis of the CAI curriculum, and the California test for basic skills CTBS. They show more improvement on the first instrument than on the second. They show more improvement than youngsters receiving only a 10-minute CAI supplement in elementary arithmetic, who show more improvement than youngsters receiving no supplement.

Within this range of variation, zero, 10, and 20 minutes daily, for a school year, achievement gains show a roughly linear relationship with intensity, that is, more time, more gain. I do not mean to imply anything more than I have said. That is, we have not tried 25 minutes or 30 minutes, and I do not want to draw any inference as to what might happen under those longer conditions.

The gains have proven cumulative over the first 2 years of the program, but preliminary analysis of the third year's data appears to show diminishing returns. It is not any surprise that the trend line of cumulative annual gains would not persist indefinitely. I prefer not to say very much about the degree of diminishing returns, but emphasize the preliminary nature of these results.

Another result is that protocols taken from youngsters receiving the CAI supplement while they solved computational problems frequently revealed the same conceptual misunderstandings of deeper mathematical processes as do protocols taken from youngsters in the control groups not receiving the CAI supplement. This appears to be coordinate with the differences in achievement gains measured by the two test instruments, one of which, the curriculum-specific test, emphasizes computation and perhaps speed and accuracy of computation, while the CTBS covers a broader range of knowledge of mathematical process.

The analyses for all 3 years reveal that the language arts and the basic reading skills curriculums are more ambiguous and uncertain in their effects on student achievement, as measured by the CTBS, than the elementary arithmetic curriculum, and more difficult to characterize. I would like to summarize these results in the following way: I would pay the cost for the effects on student learning of the elementary arithmetic CAI program. Beyond that I would pay the marginal cost for the effects of the language arts and basic reading skills programs.

There is naturally the question of how we explain the difference in effectiveness among these three curriculums. There is no way to be certain. I will hazard some explanations, one of which is that practice in punctuation and vocabulary simply bear a weaker relationship to the exercise of writing and reading skills than computation bears to mathematics. That is, we have an effective principle; it works for arithmetic, but we have not applied it suitably to writing and reading. Or, we have applied the principle suitably, but the execution is weak. That is, perhaps the computer curriculums in language arts and in basic reading skills are of lesser quality than the elementary arithmetic curriculum. This explanation is coordinated with the substantially different size in the dollar investments made in the development, test and refinement of these three curriculums.

I would like to digress briefly here, for a reason I prefer to reveal afterward, to describe another approach to improving writing and reading skills based on an idea that Prof. George A. Miller calls "automated dictionaries." Miller noted at a workshop in 1978 sponsored by the National Institute of Education that automated dictionaries might serve a variety of educational purposes in the teaching and learning of communicative skills, and that retrieval systems incorporating the new microprocessor technology could easily make automated dictionaries widely available.

He defined a number of automated dictionaries of increasing complexity, as well as a number of "automated grammars." Briefly, the simplest system that would qualify as an automated dictionary would allow a student user to designate a word, say by typing it, and receive information about the word, say its dictionary entry. He could receive that information either visually on a cathode ray tube, or auditorially by electronically generated speech.

Subsequently, Prof. Seymour Papert proposed that if the aim is to facilitate acquisition of writing and reading skills by students, the most useful device to give them might be a word processor with automated dictionary; that inasmuch as lexical knowledge is a component of writing and reading, its acquisition should not be artificially separated from the mastery of these skills. In summary, student improvement in writing and reading can best be advanced by practice in writing and reading.

One may now create and speculate on the effectiveness of a scenario of the following sort, only some of which is feasible at this time.

A student engaged in writing using a word processor with automated dictionary could be cued about a variety of language errors ranging between spelling, punctuation and incomplete sentences at one extreme, to more complex errors and instances of poor language usage at the other. For example, after completing the typing of a paragraph, the student might find himself cued something as follows:

(1) Lines 3 and 9 contain a spelling or typing error.

(2) This paragraph contains an incomplete sentence somewhere around lines 4 and 5.

(3) You use the word "development" with very high frequency. Try some substitutions for a more interesting paragraph.

(4) This paragraph contains six sentences; four of them are compound beginning with prepositional phrases, over 30 words long. This combination is generally poor writing. You may wish to try for improvement with the following changes, et cetera.

I have deliberately set about making this scenario sound plausible. The experts can tell us to what extent and within what time frame the operations I have described are technically feasible, and estimate cost projections for something like it over the next 5 to 10 years. This conceptual model for improving student achievement is only one of several currently available to us. I will mention another more briefly later. I have chosen to elaborate this one—it is relatively easy to describe—to make an observation for which we now have some limited experience. The time needed to transform a concept for improving student achievement to a working model with curriculum whose effectiveness can be tested, however, tentatively, in a school environment is long. In absolute terms, it is about 5 to 10 years. And this is very long in comparison with the rate at which dramatic changes are taking place in the hardware that is available to us.

With this first introductory observation, I will turn now to a brief, more specific discussion of the effects of public policy and private sector investment on school use of computers to improve student learning. Let me say first that I believe student use of computers is going to increase in this decade, but not sharply; that is, that the dramatically declining cost of hardware will not be matched by dramatic increases in school use. I think low acquisition cost for hardware is a necessary but not sufficient condition for increased school use. There are other determining factors, including ease of access, demonstrable effectiveness, and availability of quality computer curriculums. I will discuss each of these briefly in turn, starting with ease of access.

I have three things in mind here; Natural language input and output; computer generated audio; and speech recognition. On the first, the problems of accepting natural language input or producing acceptable informal natural language output, which the student can readily understand, is a severe barrier to accelerated use of computers in the school. Despite the occasional appearance of a breakthrough, the technical problem of accessing a computer program using natural language continues to resist solution. No doubt the current intensive efforts of developing and marketing sophisticated word processors for office use will have an important impact on the level of natural language processing that can be implemented at reasonable cost in this decade. I wish to emphasize here my sense of the importance of achieving a more sophisticated level of natural language processing than is now available to accelerate the use of computers in the schools to improve learning.

Second: I think the importance of audio to facilitate instructional use of the computer is high. There has been conspicuous progress in this area, for which both private sector investment and federally sponsored R. & D. have been responsible. Audio suitable for instructional use should be of sufficiently high quality to allow a student to listen to it for considerable periods of time without a feeling of strain.

Many would argue that programs to improve student acquisition of initial reading skills cannot be achieved without this level of audio capability. Beyond the quality of the sound, we also need the ability to synthesize messages for the student "on the fly" responsive to particular features of the students' work.

Third, is speech recognition, where our capability clearly lags that for speech generation, and which may not be available to use in a form usable to facilitate instructional use of the computer until perhaps toward the end of this decade, and perhaps not until the next. However, this is not simply a problem for instructional use of the computer. Speech recognition has wider implications for various computer uses, and development of this capability will no doubt be the object of widespread interest in both the public and private sectors.

A second factor which must surely influence school use is demonstrable effectiveness. Various elements may contribute to this, including those I have already discussed, but I wish to call special, if brief, attention to another here. It is another model to improve student learning known as intelligent computer-assisted instruction, or ICAI.

As opposed to the student model of improvement based on drill and practice, ICAI is based on the assumption that the student has internalized the representation of any skill he is using. This internal representation is primarily responsible for any errors the student commits in the execution of that skill, and most errors are not random. They occur because the student has an incorrect internal representation of the skill that he is trying to execute. Under this conceptualization, individualization of instruction can take a different and possibly much more powerful form than merely differential time spent in drill and practice.

An analysis of the errors made by the students while performing many tasks of the same class, that is, those involving application of the same skill, can lead to insight into and possibly a precise definition of the "bug"—taken from the expression "program bug"—in the student's internal representation of the skill, and which can then be corrected didactically.

Only time consuming and expensive development and research will reveal the power in the breadth of application of this model to improve student learning. Dr. John Seely Brown and his colleagues at Xerox Park are currently exploring the application of this model to mathematics instruction.

Finally, I come to the question of the sources and availability of quality computer curriculums of all kinds to improve student learning. I would like to say right off that I am unable, to my own satisfaction, to come to grips with a likely scenario for the development of a rich inventory of computer curriculums.

I believe, and you may hear otherwise during the seminar, that a rich inventory of computer curriculums is needed in order to give teachers a sense of participation in the school use of computers through the opportunity to choose from a large number, since I think we may assume that, for the foreseeable future, the classroom teacher will not be a developer of his or her own computer curriculums. This situation differs at the level of higher education, but I am confining myself here to elementary-secondary education.

The equipment vendors certainly have the capital resources necessary for development of computer curriculums, but they have no established role in public education. And presumably they have other more profitable investment opportunities.

The publishing industry is characterized by many as risk aversive, and the school market for computer curriculums is certainly not well defined and established at this time. Perhaps some special, temporary arrangements involving public—and, in that case, probably Federal support—are necessary which can be tied to the objective of demonstrating the very highest standard of curriculum quality that we can produce with our current knowledge and experience. I will leave further development of this point to the deliberations this afternoon and tomorrow of the various working groups.

I would like to close with a postscript. Contrary to some expectations in the 1960's, I believe that many would now agree that information rather than space exploration has become the dominant metaphor for the closing quarter of this century, and the television receiver and the computer its peravsive realization. Citizens in advanced societies must deal increasingly with information about things rather than with the things themselves. Some young Americans will learn this at home. But I think there is no better place to introduce the next generation of all young Americans to this compelling aspect of the future than in the schools. And there is no better way for them to learn it than by practice.

Thank you very much.

[The complete prepared statement of Mr. Melmed follows:]

COMPUTERS IN ELEMENTARY EDUCATION:
AN EVOLUTIONARY VIEW

BY

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PREPARED FOR SEMINAR ON INFORMATION TECHNOLOGY IN EDUCATION

SPONSORED JOINTLY BY:
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THERE ARE MANY APPLICATIONS IN EDUCATION OF THE NEW INFORMATION PROCESSING AND COMMUNICATION TECHNOLOGIES BASED ON THE RAPIDLY DECLINING COSTS OF STORING AND RETRIEVING INFORMATION, SENDING AND RECEIVING INFORMATION, AND TRANSFORMING AND REORGANIZING INFORMATION IN MORE OR LESS COMPLEX WAYS. YOU WILL HEAR ABOUT AND SEE SOME OF THESE DURING THE DIFFERENT SESSIONS OF THIS SEMINAR. THERE ARE VARIOUS CATEGORIES OF LEARNERS WHO MAY ENGAGE THESE AND YET NEWER APPLICATIONS NOW UNDER DEVELOPMENT WITH WHICH THE DEPARTMENT OF EDUCATION IS CONCERNED. MY TOPIC THIS MORNING HOWEVER IS THE ROLE OF THE COMPUTER TO IMPROVE LEARNING IN THE ELEMENTARY SCHOOL. IT IS AN ARENA IN WHICH WE NOW HAVE SUBSTANTIAL WORKING EXPERIENCE WITH WHICH TO ANCHOR OUR VISION OF THE FUTURE, AND IS OF CRITICAL IMPORTANCE BECAUSE IT IS CONCERNED WITH CHILDREN. I WILL NOT TRY TO FORECAST THE RATE OF ACCEPTANCE OF COMPUTERS TO IMPROVE LEARNING IN THE SCHOOLS, BUT I WILL IDENTIFY SOME FACTORS I THINK WILL AFFECT USE, AND DISCUSS SOME PUBLIC POLICY AND PRIVATE SECTOR INVESTMENT OPPORTUNITIES.

I DIVIDE THE FACTORS AFFECTING SCHOOL USE INTO TWO CATEGORIES WHICH I CALL STRUCTURAL FACTORS AND SCHOOL PROCESS FACTORS. AFTER SOME EXAMPLES AND A BRIEF DISCUSSION OF EACH, I WILL CONCENTRATE ON THE CATEGORY OF STRUCTURAL FACTORS, OR THOSE FACTORS THAT MAY AFFECT SCHOOL USE WHICH THE SCHOOLS ARE UNABLE EASILY TO INFLUENCE, AND DO NOT. SOME OBVIOUS STRUCTURAL FACTORS ARE:

(1) THE ACQUISITION COST OF EQUIPMENT.

(2) THE CAPACITY AND CAPABILITY OF EQUIPMENT.

(3) THE MAINTENANCE COST OF EQUIPMENT.

(4) THE RELIABILITY OF EQUIPMENT.

(5) THE AVAILABILITY AND COST OF COMPUTER CURRICULUMS.

(I SHOULD NOTE I GIVE VERY BROAD MEANING TO THE WORD CURRICULUMS TO INCLUDE COMPUTER ASSISTED INSTRUCTION, COMPUTER MODELING, COMPUTER SIMULATIONS, ETC.) IT IS CLEAR, IN A GENERAL WAY, THAT ACQUISITION AND MAINTENANCE COSTS ARE GOING DOWN, WHILE EQUIPMENT CAPACITY AND RELIABILITY ARE GOING UP. AND THAT THESE TRENDS WILL CONTINUE IN THE FORESEEABLE FUTURE. THE PICTURE IS DIFFERENT AND OCCASIONALLY LESS CLEAR IN THE MATTER OF SPECIAL CAPABILITIES, SAY HUMAN SPEECH RECOGNITION, AND IN THE MATTER OF COMPUTER CURRICULUMS. I WILL RETURN TO COMMENT MORE FULLY ON THESE MATTERS LATER.

AMONG THE SCHOOL PROCESS FACTORS, TWO STAND OUT:

(1) THE ACTIVATION ENERGY AND BUDGET NEEDED TO OVERCOME BARRIERS TO START-UP.

(2) MANAGEMENT FACTORS AND SOCIAL PROCESS IN THE CLASSROOM.

BARRIERS TO START-UP INCLUDE:

(1) THE BUDGET PROCESS, AND THE LOCUS OF DECISION-MAKING TO GET A NEW LINE ITEM ADDED TO THE SCHOOL BUDGET. THE DECLINING COSTS OF EQUIPMENT HAVE THE EFFECT OF REDUCING THIS BARRIER.

(2) TIME AND LEADERSHIP. VARIOUS STUDIES SHOW THAT THE TIME AVAILABLE TO PRINCIPALS TO PLAY A LEADERSHIP ROLE TO INITIATE NEW INSTRUCTIONAL UNDERTAKINGS IS SHRINKING.

(3) THE COST OF TEACHER TRAINING IN THE USE OF COMPUTERS IN THE CLASSROOM. THERE APPEARS TO EXIST A GROWING INTEREST IN VARIOUS QUARTERS FOR NEW PROGRAMS AND TECHNIQUES TO MAINTAIN

AND DEVELOP NEW TEACHER COMPETENCIES, INCLUDING TEACHER CENTERS TO BE DIRECTED BY TEACHERS THEMSELVES. AND THERE APPEARS TO BE INTEREST IN THE CONGRESS IN A NEW EDUCATION PROFESSIONS DEVELOPMENT ACT. PERHAPS THE POSSIBILITY OF NEW BUDGET TO MEET THE COST OF TEACHER TRAINING IN THE USE OF INFORMATION TECHNOLOGY IN THE CLASSROOM IS BECOMING LESS REMOTE.

MANAGEMENT FACTORS AND SOCIAL PROCESS IN THE CLASSROOM IS SURROGATE FOR A HOST OF FACTORS; FOR EXAMPLE:

(1) IF INADEQUATE ACCESS TIME TO COMPUTERS AND COMPUTER CURRICULUMS IS AVAILABLE, BY WHAT CRITERIA DOES THE CLASSROOM TEACHER ALLOCATE THIS RESOURCE TO STUDENTS?

(2) IS THE RESOURCE LOCATED INSIDE OR OUTSIDE OF THE CLASSROOM? IF OUTSIDE, HOW DOES THE TEACHER SUPERVISE THIS STUDENT ACTIVITY?

(3) WHETHER OUTSIDE OR INSIDE, HOW DOES THE TEACHER MANAGE HIS OR HER OWN TIME, AND THAT OF THE REMAINING STUDENTS WHEN ONLY SOME ARE ENGAGED IN THE USE OF THIS RESOURCE?

(4) AND SO ON.

(I MENTION IN PASSING THAT THE NATIONAL INSTITUTE OF EDUCATION IS CURRENTLY UNDERTAKING A PROGRAM OF RESEARCH TO IMPROVE OUT UNDERSTANDING OF THE RELATIONSHIP BETWEEN THIS CLUSTER OF FACTORS AND SCHOOL USE OF COMPUTERS.)

THESE SCHOOL PROCESS FACTORS ARE SEEMINGLY MORE DIFFICULT TO DISENTANGLE IN THEIR EFFECTS ON SCHOOL USE THAN THE STRUCTURAL FACTORS I IDENTIFIED PREVIOUSLY, AND AT LEAST EQUALLY IMPORTANT. PUBLIC POLICY COULD NO DOUBT STRUCTURE AN INCENTIVE SYSTEM TO STIMULATE SCHOOL USE OF COMPUTERS, BUT THERE EXISTS ALREADY A LONG MENU TO SHAPE THE ALLOCATION OF ANY NEW PUBLIC FUNDS THAT

MAY BECOME AVAILABLE FOR EDUCATION. HOW THEN CAN A PRIORITY ALLOCATION BE ASSERTED TO MEET THE ADDED COST FOR THE USE OF COMPUTERS IN THE SCHOOLS TO IMPROVE STUDENT LEARNING? PERHAPS BY THE USE OF EFFECTIVENESS DATA, WHICH PRESUMABLY AFFECT THE BEHAVIORS OF BOTH POLICY MAKERS AND PRACTITIONERS ALIKE. SO WHAT EFFECTIVENESS DATA TO IMPROVE STUDENT LEARNING DO WE HAVE? AND WHAT CAN WE INFER FROM THESE DATA?

THERE ARE EFFECTIVENESS DATA OF DIFFERENT QUANTITY AND QUALITY ON VARIOUS COMPUTER CURRICULUMS AND VARIOUS APPLICATIONS OF COMPUTERS TO IMPROVE LEARNING IN THE SCHOOLS. YOU WILL BE LEARNING MORE ABOUT THESE DURING DIFFERENT SESSIONS OF THIS SEMINAR. BUT PERHAPS OUR BEST SCHOOL USE DATA FROM A NARROW, TECHNICAL POINT OF VIEW ARE BASED ON THAT MODEL OF COMPUTER USE KNOWN AS COMPUTER ASSISTED INSTRUCTION, OR DRILL-AND-PRACTICE, AS OPPOSED SAY TO COMPUTER MODELING AND COMPUTER SIMULATIONS, ETC., AND IS BASED ON SOME COMPUTER CURRICULUMS DEVELOPED BY PROF. SUPPES AND HIS COLLEAGUES AT STANFORD UNIVERSITY IN THE LATE 1960's AND EARLY 1970's.

LIMITED CLUSTERS OF (CROSS-SECTIONAL) DATA ON STUDENT USE HAVE LONG BEEN AVAILABLE SUGGESTING A LINEAR RELATIONSHIP BETWEEN IMPROVED ACHIEVEMENT IN ELEMENTARY ARITHMETIC AND ACCESS TIME (OR TIME ON TERMINAL) TO THE ELEMENTARY ARITHMETIC COMPUTER CURRICULUM FOR PERIODS UP TO A SCHOOL YEAR; THAT IS, WITHIN RELATIVELY NARROW LIMITS OF UP TO TEN MINUTES PER SCHOOL DAY, STUDENT ACHIEVEMENT APPEARED TO SHOW IMPROVEMENT PROPORTIONAL TO TIME ON TERMINAL, BEYOND WHAT MIGHT HAVE OTHERWISE BEEN

EXPECTED. OBVIOUSLY, EVEN IF TRUE, THIS IS NOT A PHENOMENON WHICH CAN BE EXPECTED TO PERSIST INDEFINITELY, AND IS NOT ENTIRELY INDEPENDENT OF OTHER CONDITIONS OF INSTRUCTION SUCH AS CLASSROOM TEACHING, BUT AS THE AMOUNT OF THE FEDERAL SUPPLEMENT FOR COMPENSATORY EDUCATION FOR THE INDIVIDUAL STUDENT ROSE TO MEET THE DECLINING COST OF COMPUTER ASSISTED INSTRUCTION, THE NATIONAL INSTITUTE OF EDUCATION IN 1976 SPONSORED A FIVE-YEAR LONGITUDINAL EVALUATION OF THESE CURRICULUMS IN SEVERAL SCHOOLS IN THE LOS ANGELES UNIFIED SCHOOL DISTRICT. THE STUDY, NOW IN ITS FOURTH FULL YEAR OF DATA COLLECTION, HAD SEVERAL OBJECTIVES:

(1) TO ASSESS THE EFFECTS OF SEVERAL YEARS OF COMPUTER ASSISTED INSTRUCTION (CAI) ON STUDENT ACHIEVEMENT IN EACH OF THREE CURRICULUMS: ELEMENTARY ARITHMETIC, LANGUAGE ARTS AND INITIAL READING SKILLS.

(2) TO ASSESS THE EFFECTS OF VARIATIONS IN THE INTENSITY (AS OPPOSED TO THE DURATION) OF CAI ON STUDENT ACHIEVEMENT; AND,

(3) TO ATTEMPT TO ASSESS THE EFFECTS OF CAI IN ELEMENTARY ARITHMETIC ON THE STUDENT'S CONCEPTUAL UNDERSTANDING OF MATHEMATICAL PROCESSES.

THE EVALUATION IS BEING CONDUCTED BY THE EDUCATIONAL TESTING SERVICE OF PRINCETON, N. J., AND REPORTS ARE AVAILABLE FROM THEM ON THE DESIGN AND CONDUCT OF THE STUDY. AN ANALYSIS OF THE FIRST TWO YEARS OF DATA IS COMPLETE; A PRELIMINARY ANALYSIS OF THE THIRD YEAR'S DATA HAS JUST BECOME AVAILABLE; AND I WOULD LIKE TO GIVE YOU MY ROUGH-AND-READY SENSE OF THE MEANING OF THESE RESULTS, WITHOUT VARIOUS STATISTICAL

QUALIFICATIONS.

BRIEFLY, THIS STUDY INCLUDES MAINLY THREE EXPERIMENTAL GROUPS AND TWO CONTROL GROUPS MADE UP OF COMPARABLE YOUNGSTERS ATTENDING SCHOOLS ELIGIBLE FOR TITLE I (ESEA) FUNDS. THE GROUPS INCLUDE YOUNGSTERS FROM GRADES ONE THROUGH SIX ELIGIBLE FOR COMPENSATORY INSTRUCTION, AND RANDOMLY ASSIGNED AMONG THE EXPERIMENTAL GROUPS. SOME YOUNGSTERS ARE ASSIGNED TWO TEN MINUTE TIME PERIODS PER DAY ON THE ELEMENTARY ARITHMETIC COMPUTER CURRICULUM, SOME TEN MINUTES, AND SOME NONE. YOUNGSTERS IN THE EXPERIMENTAL GROUP ASSIGNED TEN MINUTES ARE ASSIGNED AN ADDITIONAL TEN MINUTE TIME PERIOD ON EITHER OF THE OTHER TWO COMPUTER CURRICULUMS, LANGUAGE ARTS OR INITIAL READING SKILLS. AND YOUNGSTERS MAKING UP THE THIRD EXPERIMENTAL GROUP AND NOT ASSIGNED ANY TIME ON THE ELEMENTARY ARITHMETIC COMPUTER CURRICULUM ARE ASSIGNED A TEN MINUTE TIME PERIOD ON EACH OF THE OTHER TWO. TWO CONTROL GROUPS ARE MADE UP OF YOUNGSTERS NOT ASSIGNED ANY COMPUTER TIME: ONE FOR INTR-SCHOOL COMPARISONS MADE UP OF YOUNGSTERS DRAWN FROM SCHOOLS HOUSING THE COMPUTER EQUIPMENT USED IN THE STUDY; AND THE OTHER FOR INTER-SCHOOL COMPARISONS MADE UP OF YOUNGSTERS DRAWN FROM SCHOOLS NOT HOUSING ANY EQUIPMENT. ANALYSES OF THE DATA REVEAL THE FOLLOWING.

YOUNGSTERS RECEIVING A TWENTY MINUTE SUPPLEMENT IN ELEMENTARY ARITHMETIC DAILY SHOW ACHIEVEMENT GAINS BEYOND WHAT MIGHT HAVE OTHERWISE BEEN EXPECTED ON TWO SEPARATE TEST

INSTRUMENTS, A CURRICULUM SPECIFIC TEST DESIGNED TO MATCH THE STRONGLY COMPUTATIONAL EMPHASIS OF THE CAI CURRICULUM, AND THE CALIFORNIA TEST FOR BASIC SKILLS (CTBS). THEY SHOW MORE IMPROVEMENT ON THE FIRST INSTRUMENT THAN ON THE SECOND. THEY SHOW MORE IMPROVEMENT THAN YOUNGSTERS RECEIVING ONLY A TEN MINUTE CAI SUPPLEMENT IN ELEMENTARY ARITHMETIC, WHO SHOW MORE IMPROVEMENT THAN YOUNGSTERS RECEIVING NO SUPPLEMENT. WHITHIN THIS RANGE OF VARIATION -- ZERO, TEN AND TWENTY MINUTES DAILY --ACHIEVEMENT GAINS SHOW A ROUGHLY LINEAR RELATIONSHIP WITH INTENSITY; i.e., MORE TIME, MORE GAIN.

THE GAINS ARE CUMULATIVE OVER THE FIRST TWO YEARS OF THE PROGRAM. BUT PRELIMINARY ANALYSIS OF THE THIRD YEAR'S DATA APPEARS TO SHOW DIMINSHING RETURNS. IT IS NO SURPRISE THAT THE TREND LINE OF CUMULATIVE ANNUAL GAINS WILL NOT PERSIST INDEFINITELY, BUT

I WISH TO EMPHASIZE THE PRELIMINARY NATURE OF THIS RESULT. ANOTHER RESULT IS THAT PROTOCOLS TAKEN FROM YOUNGSTERS RECEIVING THE CAI SUPPLEMENT WHILE THEY SOLVED COMPUTATIONAL PROBLEMS FREQUENTLY REVEALED THE SAME CONCEPTUAL MISUNDERSTANDINGS OF MATHEMATICAL PROCESS AS DO PROTOCOLS TAKEN FROM YOUNGSTERS IN THE CONTROL GROUPS NOT RECEIVING THE CAI SUPPLEMENT. THIS APPEARS TO BE COORDINATE WITH THE DIFFERENCES IN ACHIEVEMENT GAINS MEASURED BY THE TWO TEST INSTRUMENTS, ONE OF WHICH, THE CURRICULUM SPECIFIC TEST, EMPHASIZES COMPUTATION AND PERHAPS SPEED AND ACCURACY OF COMPUTATION, WHILE THE CTBS COVERS A BROADER RANGE OF KNOWLEDGE OF MATHEMATICAL PROCESS.

THE ANALYSES FOR ALL THREE YEARS REVEAL THAT THE LANGUAGE ARTS AND INITIAL READING SKILLS CURRICULUMS ARE MORE AMBIGUOUS AND UNCERTAIN IN THEIR EFFECTS ON STUDENT ACHIEVEMENT, AS MEASURED BY THE CTBS, THAN THE ELEMENTARY ARITHMETIC CURRICULUM, AND MORE DIFFICULT TO CHARACTERIZE. I FIND IT CONVENIENT TO SUMMARIZE THESE RESULTS IN THE FOLLOWING WAY: I WOULD PAY THE COST FOR THE EFFECTS ON STUDENT LEARNING OF THE ELEMENTARY ARITHMETIC CAI PROGRAM. BEYOND THAT, I WOULD PAY THE MARGINAL COSTS FOR THE EFFECTS OF THE LANGUAGE ARTS AND INITIAL READING SKILLS PROGRAMS. HOW DO WE EXPLAIN THE DIFFERENCE IN EFFECTIVENESS AMONG THESE THREE CURRICULUMS?

WE CAN NOT BE CERTAIN. ONE POSSIBLE EXPLANATION IS THAT PRACTICE IN PUNCTUATION AND VOCABULARY BEARS A WEAKER RELATIONSHIP TO THE EXERCISE OF WRITING AND READING SKILLS THAN COMPUTATION BEARS TO MATHEMATICS. THAT IS, WE HAVE AN EFFECTIVE PRINCIPLE; IT WORKS FOR ARITHMETIC; BUT WE HAVEN'T APPLIED IT SUITABLY TO WRITING AND READING. OR, WE HAVE APPLIED THE PRINCIPLE SUITABLY, BUT THE EXECUTION IS WEAK. THAT IS, PERHAPS THE COMPUTER CURRICULUMS IN LANGUAGE ARTS AND INITIAL READING SKILLS ARE OF LESSER QUALITY THAN THE ELEMENTARY ARITHMETIC CURRICULUM. THIS EXPLANATION IS COORDINATE WITH THE SUBSTANTIALLY DIFFERENT SIZE IN THE DOLLAR INVESTMENTS MADE IN THE DEVELOPMENT, TEST AND REFINEMENT OF THESE THREE CURRICULUMS.

I WOULD LIKE TO DIGRESS BRIEFLY HERE, FOR A REASON I WILL

REVEAL SHORTLY, TO DESCRIBE ANOTHER APPROACH TO IMPROVING WRITING AND READING SKILLS BASED ON AN IDEA PROF. GEORGE A. MILLER CALLS "AUTOMATED DICTIONARIES". MILLER NOTED AT A SUMMER WORKSHOP SPONSORED BY THE NATIONAL INSTITUTE OF EDUCATION IN AUGUST 1978 THAT AUTOMATED DICTIONARIES MIGHT SERVE A VARIETY OF EDUCATIONAL PURPOSES IN THE TEACHING AND LEARNING OF COMMUNICATIVE SKILLS, AND THAT RETRIEVAL SYSTEMS INCORPORATING THE NEW MICROPROCESSOR TECHNOLOGY COULD EASILY MAKE AUTOMATED DICTIONARIES WIDELY AVAILABLE. HE DEFINED A NUMBER OF AUTOMATED DICTIONARIES OF INCREASING COMPLEXITY AS WELL AS A NUMBER OF "AUTOMATED GRAMMARS". THE SIMPLEST SYSTEM THAT WOULD QUALIFY AS AN AUTOMATED DICTIONARY WOULD ALLOW A STUDENT USER TO DESIGNATE A WORD (e.g., BY TYPING IT) AND RECEIVE INFORMATION ABOUT IT (e.g., ITS DICTIONARY ENTRY), EITHER VISUALLY (e.g., ON A CATHODE RAY TUBE OR EQUIVALENT), OR AUDITORILY (e.g., BY ELECTRONICALLY GENERATED SPEECH).

SUBSEQUENTLY, PROF. SEYMOUR PAPERT PROPOSED THAT, IF THE AIM IS TO FACILITATE THE ACQUISITION OF WRITING AND READING SKILLS BY STUDENTS, THE MOST USEFUL DEVICE TO GIVE THEM MIGHT BE A WORD PROCESSOR WITH AUTOMATED DICTIONARY; THAT INASMUCH AS LEXICAL KNOWLEDGE IS A COMPONENT OF WRITING AND READING, ITS ACQUISITION SHOULD NOT BE ARTIFICIALLY SEPARATED FROM THE MASTERY OF THESE SKILLS. IN SUMMARY, STUDENT IMPROVEMENT IN WRITING AND READING CAN BEST BE ADVANCED BY PRACTICE IN WRITING AND READING.

ONE MAY NOW CREATE AND SPECULATE ON THE EFFECTIVENESS OF A SCENARIO OF THE FOLLOWING SORT, ONLY SOME OF WHICH IS FEASIBLE AT THIS TIME. A STUDENT ENGAGED IN WRITING USING A WORD PROCESSOR WITH AUTOMATED DICTIONARY COULD BE CUED ABOUT A VARIETY OF LANGUAGE ERRORS RANGING BETWEEN SPELLING, PUNCTUATION, AND INCOMPLETE SENTENCES AT THE ONE EXTREME TO MORE COMPLEX ERRORS AND INSTANCES OF POOR LANGUAGE USAGE AT THE OTHER. FOR EXAMPLE, AFTER COMPLETING THE TYPING OF A PARAGRAPH, THE STUDENT MIGHT FIND HIMSELF CUED SOMETHING AS FOLLOWS:

(1) LINES THREE AND NINE CONTAIN A SPELLING OR TYPING ERROR.

(2) THIS PARAGRAPH CONTAINS AN INCOMPLETE SENTENCE SOMEWHERE AROUND LINES FOUR AND FIVE.

(3) YOU USE THE WORD "DEVELOPMENT" WITH VERY HIGH FREQUENCY. TRY SOME SUBSTITUTIONS FOR A MORE INTERESTING PARAGRAPH.

(4) THIS PARAGRAPH CONTAINS SIX SENTENCES -- FOUR COMPOUND, BEGINNING WITH PREPOSITIONAL PHRASES -- OVER THIRTY WORDS LONG. THIS COMBINATION IS GENERALLY POOR WRITING. YOU MAY WISH TO TRY FOR IMPROVEMENT WITH THE FOLLOWING CHANGES; etc.

I HAVE DELIBERATELY SET ABOUT MAKING THIS SCENARIO SOUND PLAUSIBLE. THE EXPERTS CAN TELL US TO WHAT EXTENT AND WITHIN WHAT TIME FRAME THE OPERATIONS I HAVE DESCRIBED ARE TECHNICALLY FEASIBLE, AND ESTIMATE COST PROJECTIONS FOR SOMETHING LIKE IT OVER THE NEXT FIVE TO TEN YEARS. THIS CONCEPTUAL MODEL FOR IMPROVING STUDENT ACHIEVEMENT IS ONLY ONE OF SEVERAL CURRENTLY AVAILABLE TO US. I WILL MENTION ANOTHER MORE BRIEFLY LATER. I HAVE CHOSEN TO ELABORATE THIS ONE -- IT IS RELATIVELY EASY TO

DESCRIBE -- TO VENTURE AN OBSERVATION FOR WHICH WE NOW HAVE SOME LIMITED EXPERIENCE. AND THAT IS, THAT THE TIME NEEDED TO TRANSFORM A CONCEPT FOR IMPROVING STUDENT ACHIEVEMENT TO A WORKING MODEL WITH CURRICULUM WHOSE EFFECTIVENESS CAN BE TESTED TENTATIVELY IN A SCHOOL ENVIRONMENT IS LONG; IN ABSOLUTE TERMS, SAY FIVE TO TEN YEARS; AND VERY LONG BY COMPARISON WITH THE RATE AT WHCIH DRAMATIC CHANGES ARE TAKING PLACE IN THE HARDWARE AVAILABLE TO US.

WITH THIS INTRODUCTORY OBSERVATION, I WILL TURN NOW TO A BRIEF, MORE SPECIFIC DISCUSSION OF THE EFFECTS OF PUBLIC POLICY AND PRIVATE SECTOR INVESTMENT ON SCHOOL USE OF COMPUTERS TO IMPROVE STUDENT LEARNING. LET ME SAY FIRST THAT I BELIEVE SCHOOL USE OF COMPUTERS FOR THIS PURPOSE IS GOING TO INCREASE IN THIS DECADE, BUT NOT SHARPLY, i.e., THAT THE DRAMATICALLY DECLINING COST OF HARDWARE WILL NOT BE MATCHED BY DRAMATIC INCREASES IN SCHOOL USE. I THINK LOW ACQUISITION COST FOR HARDWARE IS A NECESSARY BUT NOT SUFFICIENT CONDITION FOR INCREASED SCHOOL USE. OTHER DETERMINING FACTORS ARE EASE OF ACCESS, DEMONSTRABLE EFFECTIVENESS, AND THE AVAILABILITY OF QUALITY COMPUTER CURRICULUMS. I WILL DISCUSS EACH OF THESE IN TURN, STARTING WITH EASE OF ACCESS, AND I HAVE THREE THINGS IN MIND HERE: NATURAL-LANGUAGE INPUT AND OUTPUT, COMPUTER-GENERATED AUDIO, AND SPEECH RECOGNITION.

(1) THE PROBLEMS OF ACCEPTING NATURAL-LANGUAGE INPUT OR PRODUCING ACCEPTABLE INFORMAL NATURAL-LANGUAGE OUTPUT IS A SEVERE BARRIER, I BELIEVE, TO ACCELERATED CLASSROOM USE OF

COMPUTERS. DESPITE THE OCCASIONAL APPEARANCE OF A BREAKTHROUGH, THE TECHNICAL PROBLEM OF ACCESSING A COMPUTER PROGRAM USING NATURAL LANGUAGE CONTINUES TO RESIST SOLUTION. NO DOUBT THE CURRENT INTENSIVE EFFORTS OF DEVELOPING AND MARKETING SOPHISTICATED WORD PROCESSORS FOR OFFICE USE WILL HAVE AN IMPORTANT IMPACT ON THE LEVEL OF NATURAL-LANGUAGE PROCESSING THAT CAN BE IMPLEMENTED AT REASONABLE COST. BUT I WISH TO EMPHASIZE HERE MY SENSE OF THE IMPORTANCE OF ACHIEVING A MORE SOPHISTICATED LEVEL OF NATURAL-LANGUAGE PROCESSING THAN IS NOW AVAILABLE TO ACCELERATE THE USE OF COMPUTERS IN THE SCHOOLS TO IMPROVE LEARNING.

(2) I THINK THE IMPORTANCE OF AUDIO TO FACILITATE INSTRUCTIONAL USE OF THE COMPUTER IS ALSO HIGH, AND THERE HAS BEEN CONSPICUOUS PROGRESS IN THIS AREA FOR WHICH BOTH PRIVATE SECTOR INVESTMENT AND FEDERALLY-SPONSORED R&D ARE RESPONSIBLE. AUDIO SUITABLE FOR INSTRUCTIONAL USE SHOULD BE OF SUFFICIENTLY HIGH QUALITY TO ALLOW A STUDENT TO LISTEN TO IT FOR CONSIDERABLE PERIODS OF TIME WITHOUT A FEELING OF STRAIN. BEYOND THE QUALITY OF THE SOUND, WE NEED TO BE ABLE TO SYNTHESIZE MESSAGES "ON THE FLY" RESPONSIVE TO PARTICULAR FEATURES OF A STUDENT'S WORK.

(3) OUR CAPABILITY FOR SPEECH RECOGNITION LAGS THAT OF SPEECH GENERATION VERY SIGNIFICANTLY, AND SPEECH RECOGNITION MAY NOT BE AVAILABLE IN A FORM USABLE TO FACILITATE INSTRUCTIONAL USE OF THE COMPUTER UNTIL THE NEXT DECADE. THIS IS NOT SIMPLY A PROBLEM FOR INSTRUCTIONAL USE OF THE COMPUTER, BUT HAS WIDE IMPLICATIONS FOR VARIOUS COMPUTER USES, AND DEVELOPMENT OF THIS CAPABILITY WILL NO DOUBT BE THE OBJECT OF WIDESPREAD INTEREST IN BOTH THE PUBLIC AND

PRIVATE SECTORS.

A SECOND FACTOR THAT MUST SURELY INFLUENCE SCHOOL USE IS DEMONSTRABLE EFFECTIVENESS. VARIOUS ELEMENTS MAY CONTRIBUTE TO DEMONSTRABLE EFFECTIVENESS, INCLUDING THOSE ALREADY DISCUSSED HERE, BUT THE ONE I WISH TO CALL SPECIAL, IF BRIEF, ATTENTION TO NOW IS A MODEL TO IMPROVE STUDENT LEARNING KNOWN AS INTELLIGENT COMPUTER ASSISTED INSTRUCTION, OR ICAI. AS OPPOSED TO THE STUDENT MODEL OF IMPROVEMENT BASED ON DRILL-AND-PRACTICE, ICAI IS BASED ON THE ASSUMPTION THAT THE STUDENT HAS INTERNALIZED A REPRESENTATION OF ANY SKILL HE IS USING. THIS INTERNAL REPRESENTATION IS PRIMARILY RESPONSIBLE FOR ANY ERRORS COMMITTED IN THE EXECUTION OF THE SKILL, AND ONLY A FEW OF THE ERRORS THAT OCCUR CAN BE CONSIDERED RANDOM. UNDER THIS CONCEPTUALIZATION, INDIVIDUALIZATION OF INSTRUCTION CAN TAKE A DIFFERENT, POSSIBLY MORE POWERFUL FORM THAN DIFFERENTIAL TIME SPENT IN DRILL-AND-PRACTICE. RATHER, AN ANALYSIS OF THE ERRORS MADE BY A STUDENT WHILE PERFORMING MANY TASKS OF THE SAME CLASS, THAT IS, THOSE INVOLVING APPLICATION OF THE SAME SKILL, CAN LEAD TO INSIGHT INTO, AND POSSIBLY EVEN PRECISE DEFINITION OF THE "BUG" -- TAKEN FROM THE EXPRESSION "PROGRAM BUG" -- IN THE STUDENT'S REPRESENTATION OF THE SKILL, AND WHICH CAN THEN BE CORRECTED DIDACTICALLY. ONLY TIME CONSUMING AND EXPENSIVE DEVELOPMENT AND RESEARCH WILL REVEAL THE POWER AND BREADTH OF APPLICATION OF THIS MODEL TO IMPROVE STUDENT LEARNING. DR. JOHN SEELY BROWN AND HIS COLLEAGUES AT XEROX PARC ARE CURRENTLY EXPLORING ITS APPLICATION TO MATHEMATICS INSTRUCTION.

FINALLY, I COME TO THE QUESTION OF THE SOURCES AND AVAILABILITY OF COMPUTER CURRICULUMS -- OF ALL KINDS -- TO IMPROVE STUDENT LEARNING. I SHOULD SAY RIGHT NOW I'M UNABLE TO MY OWN SATISFACTION TO COME TO GRIPS WITH A LIKELY SCENARIO FOR THE DEVELOPMENT OF A RICH INVENTORY OF COMPUTER CURRICULUMS. I BELIEVE A RICH INVENTORY OF COMPUTER CURRICULUMS IS NEEDED TO GIVE TEACHERS A SENSE OF PARTICIPATION IN THE SCHOOL USE OF COMPUTERS THROUGH THE OPPORTUNITY TO CHOOSE FROM A LARGE NUMBER, SINCE I THINK WE MAY ASSUME THAT, FOR THE FORESEEABLE FUTURE, THE CLASSROOM TEACHER WILL NOT BE A DEVELOPER OF HIS OR HER OWN COMPUTER CURRICULUMS. THIS SITUATION DIFFERS SOME AT THE LEVEL OF HIGHER EDUCATION.

EQUIPMENT VENDORS CERTAINLY HAVE THE CAPITAL RESOURCES NECESSARY FOR DEVELOPMENT OF COMPUTER CURRICULUMS, BUT HAVE NO ESTABLISHED ROLE IN PUBLIC EDUCATION, AND PRESUMABLY HAVE OTHER MORE PROFITABLE INVESTMENT OPPORTUNITIES. THE PUBLISHING INDUSTRY IS CHARACTERIZED BY MANY AS RISK AVERSIVE, AND THE SCHOOL MARKET FOR COMPUTER CURRICULUMS IS CERTAINLY NOT WELL DEFINED AND ESTABLISHED AT THIS TIME. PERHAPS SOME SPECIAL, TEMPORARY ARRANGEMENTS INVOLVING PUBLIC, PROBABLY FEDERAL, SUPPORT ARE NECESSARY, WHICH CAN BE TIED TO THE OBJECTIVE OF DEMONSTRATING THE VERY HIGHEST STANDARD OF CURRICULUM QUALITY WE CAN PRODUCE WITH OUR CURRENT KNOWLEDGE AND EXPERIENCE. I LEAVE FURTHER DEVELOPMENT OF THIS POINT TO THE DELIBERATIONS THIS AFTERNOON AND TOMORROW OF THE VARIOUS WORKING GROUPS.

I WOULD LIKE TO CLOSE WITH A POSTSCRIPT. CONTRARY TO SOME EXPECTATIONS IN THE 1960's, I BELIEVE MANY WOULD NOW AGREE THAT INFORMATION RATHER THAN SPACE HAS BECOME THE DOMINANT METAPHOR FOR THE CLOSING QUARTER OF THIS CENTURY, AND THE TELEVISION RECEIVER AND THE COMPUTER ITS PERVASIVE REALIZATION. CITIZENS IN ADVANCED SOCIETIES MUST DEAL INCREASINGLY WITH INFORMATION ABOUT THINGS, RATHER THAN WITH THE THINGS THEMSELVES. SOME YOUNG AMERICANS WILL LEARN THIS AT HOME. BUT THERE IS NO BETTER PLACE TO INTRODUCE THE NEXT GENERATION OF ALL YOUNG AMERICANS TO THIS COMPELLING ASPECT OF THE FUTURE THAN IN THE SCHOOLS; AND NO BETTER WAY FOR THEM TO LEARN IT THAN BY PRACTICE.

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Mr. BROWN. Thank you very much, Mr. Melmed. You may assume the throne up here, if you will.

May I take this time to introduce another member of the Science Committee, the distinguished ranking member of the Science, Research and Technology Subcommittee, Mr. Hollenbeck of New Jersey.

Do you have any comments at this time, Mr. Hollenbeck?

Mr. HOLLENBECK. Thank you for the kind introduction.

We all thank you for chairing these hearings today. I will just make a very brief remark and insert some remarks into the record of the hearing.

Mr. BROWN. That is done without objection.

[The complete statement of Hon. Harold C. Hollenbeck is as follows:]

OPENING STATEMENT

HON. HAROLD C. HOLLENBECK, RANKING MINORITY MEMBER
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
JOINT HEARINGS ON
INFORMATION TECHNOLOGY IN EDUCATION
April 1, 1980

Mr. Chairman, it's time to take a fresh look at the role of information technology and American education. For the past 25 years information technology in the form of TV, radio, and computers has tried to make inroads into our public schools and universities without much success. Information technology seems to work well in training environments with tightly defined objectives, but it has not fit into the more loosely defined objectives of the educational system.

By its nature, information technology must be an invited guest in the classroom. As new technology becomes more "friendly" to the teacher, it may be invited back more often. If it helps the teacher and is not too expensive, it may even become an actual part of the classroom experience.

Information technology in the form of computers, telephones and copying machines have made inroads into the business world. Office workers are somewhat comfortable with this technology and could conceivably use it as a medium of instruction with or without teacher assistance.

I wonder if adults will bring information technology from the office into the home; or will advertising of computerized video toys make the home the entry point of information technology into educational practice.

I think the future of information technology in education will be determined by the answers to three questions. Number one: Can information technology reduce the costs of education to a point where all citizens can enjoy equal access throughout their entire lives?

Number two: Has the state of the art of information technology progressed where the learning experience is superior to that of the traditional classroom situation?

And, finally, will labor intensive educational institutions choose hardware over human resources in the politicized budgeting process?

Mr. Chairman, based on past acceptance by teachers, information technology may never become a vital part of the educational establishment. However, it does hold tremendous promise for learning in the office or the home. Information technology can bring extensive bibliographic resources, rich visual experiences, and problem solving simulations into the hands of learners for prices that are becoming comparable to school textbooks.

I thank these distinguished witnesses for helping our two subcommittees gain a better understanding of how information technology can contribute to education, either in the school or out of the school.

Thank you, Mr. Chairman.

Mr. **Hollenbeck**. I know that we're on a limited time basis, and I have a plane to catch, but I know that all of us here are interested in seeing how we may achieve realization of the potential educational benefits of the information technologies that we are discussing today. There are some obvious issues involved with the development and with achievement which our panels will be discussing. I am looking forward to reading the transcript of the hearing, and I apologize for having to leave the hearing in several minutes.

But thank you again, Mr. Chairman. You are to be commended for your interest and for your endeavors in this regard.

Mr. **Brown**. Thank you. We always like little commendations.

Our next witness is Dr. Dustin Heuston who has had a long and distinguished career in education at all levels, from college teaching and administration to elementary and secondary levels of teaching and administration. He has, for the past 2 or 3 years, held the position of chairman of the World Institute for Computer Assisted Teaching, an organization that I am looking forward to learning more about, and we welcome Dr. Heuston at this time for his statement.

STATEMENT OF DR. DUSTIN HEUSTON, CHAIRMAN, WICAT

Dr. **Heuston**. Thank you.

I have some charts which I ask to be held up one by one. I do not necessarily want to imply metaphorically that this is an optimal role for NSF leadership—the charts are being held by Dr. Joseph Lipson of the National Science Foundation. The truth is our technology broke down, and here we have another definitive example of our need for human support instead of just pure technology.

Now for those behind the chairs who cannot see the charts, I have given a handout that has an identical picture of the contents of the charts.[1]

Speaking for many of us, I would like to also compliment you, Chairman Brown, for your articulate and accurate statement and also for your unusual dedication and competence in running your hearings. Many of us have come to many hearings in Washington and yours surely stand out because of the leadership. It is an honor and a privilege to be involved in a proceeding in which the leader shows such courtesy and thoughtful commitment.

It is also a pleasure to address this group. I see many old faces and old friends who have been in the trenches, and I do not want to count the decades that we have spent working together to make the technology a success.

I would like to compliment Arthur Melmed for his leadership in this important field. Arthur kept the faith when there was a political cost to do this. Many of us have appreciated that. He has worked very hard to nourish and sustain many workers who tried for the past 15 or 20 years to obtain support in continued research in these important areas. We knew it was coming. We could not always get a hearing, but Arthur was always there working hard, and we appreciate it.

Mr. **Melmed**. Thank you.

Dr. **Heuston**. I also agree with Arthur's excellent summary of the status of the field.

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[1] A copy of the charts begin on p. 48. The number of the chart referred to is indicated in the text.

Now it is time to turn to the first chart. My concern here is to discuss trends that are similar for various levels of education, such as the elementary, secondary, college, and adult training markets. Even though the information is not always appropriate to a listener's particular interest, the principles will remain true for each level, and I will make some attempt to go back and forth in my discussion between the various levels.

As this first chart indicates, the dominant metaphor in education is the loving teacher working individually with the student. This metaphor is one that blocks our thinking about what is actually happening in the school system, and as long as we hold it at the center of our thought processes, we will never be able to understand the limits of the current educational delivery system.

The second chart offers a clearer statement of what the actual metaphor should be. What this metaphor indicates is that there is an average of 25 to 30 students in every classroom with a teacher. Thus the teacher cannot interact personally with those students on an individual basis, no matter how committed he or she is.

As a matter of fact, there is some rather discouraging data as to how much teachers can interact with their students. Before turning to these data, however, I want to show you next the constitution of a typical eighth grade class in terms of the grade levels on which each student is performing in any given class (Chart 3). It is important that the listener understand that a teacher is not only talking to the eighth grade, but an eighth grade consisting of students who are performing at various grade levels that have nothing to do with the general system average called the eighth grade. A good rule for discussing the differences in a typical elementary school situation is to say that there are as many years of difference in the students' ability in any given class as there are in the years represented by the grade level. Thus in a typical eighth grade classroom there are apt to be 8 years of difference in the ability of the student population. In other words, a student might be working at anywhere from, say, the fourth grade level through the 12th grade level. In the sixth grade, the difference in student abilities is probably about a 6-year spread. As the students get older, the differences spread. Thus the teacher not only has to deal with 25 to 30 students in a classroom, but also with a broad range of ability levels in those 25 to 30 students.

Now let me turn to some of the hard data that is very discouraging in studying how much individual attention a student can have using the warm metaphor of a teacher working individually with a student (Chart 4). Two excellent studies have been made, one by Conant and another by Christiansen, which show that the current educational delivery system cannot give a student more than 1 minute a day of individual instruction from a teacher. This is a system-wide average that can be violated at any time on an individual student basis, but still retains the average characteristics for the group as a whole. As the chart shows, the 1-minute-a-day figure breaks down to 10 seconds for every hour that the student spends in a classroom. This means that a student is allowed approximately 1/360 of his time with individual instruction under a loving teacher's care. Restated in terms of a school year, which may have 180 days of instruction, the student will have one-half of 1 of his days of instruction during the entire school year in an individual mode.

In other words, no matter how the school leadership states that it loves each and every child, the student is still restricted to 1/360 of his or her time where instruction is received that is appropriate precisely to individual needs and interests.

Now unless we understand these statistics in our bones and refuse to allow ourselves to think of a loving teacher metaphor as the dominant condition of the educational delivery system, we will be forever chasing rainbows in our funding policies as we attempt to improve our educational system. Generally speaking, a teacher cannot devote more time than the system average to his or her students. Obviously there may be many teachers who do perform at a much higher level of performance, but surely there are also teachers who perform at a less than optimal level, thus producing the true system average that has been so carefully documented.

Thus, try as we may, the system average keeps coming out to the same level. If we want to help education, we must understand this clearly and put our resources into those areas which can help to increase individual instruction, or else we cannot come to terms with the fundamental limits of the current educational delivery system.

Stated another way, the failure of the current delivery system is that it does not allow a learner adequate productivity. Almost all of our national efforts and almost all of our national rhetoric discussing educational productivity is handled exclusively in terms of how productive the teacher is. Unfortunately, the teacher, after 500 years of experimentation, is about as productive as we can make him or her. Although the teacher works very hard with the 25 to 30 students, there simply is a limit to how productive he or she can be within constraints of the system.

Some of our early efforts have been to use technology to extend the productivity of the teacher directly by putting the teacher on tape or broadcasting his or her image through a television tube. Increasing the teacher productivity in this way does little to aid the student whose need for productivity is increasing his individual attention in those areas where he or she needs fundamental help. Stated another way, the real problem of the educational delivery system is "learner productivity," and not "teacher productivity." Thus we are going to have to become sensitive to a new phrase in our culture, "learner productivity."

The great need in the future will be increasing learner productivity from the 10 seconds per hour for individual instruction to some high multiple of this amount (Chart 5). Unless this critical problem of learner productivity in the form of individual instruction is addressed, the delivery system will not improve no matter how much capital is put into it.

The use of technology is the most obvious method for improving learner productivity in terms of individual interactive instruction. Unfortunately, technology has a very seriously distorted negative image when placed against the dominant metaphor of the loving teacher working with the individual student. Even more importantly, the technology that can help the student improve the productivity of his educational experience is restricted to those technologies which have a computer present in the instructional process. It is important to understand that television or videotape or movies lack this requisite capability, and hence they cannot make a very serious contribution to helping the student with individual instruction.

The next chart (Chart 6) is a description of what is happening in terms of the labor market, and furthermore, what is happening to our children and the implications for them in the labor markets of the future. What the graph shows is that the amount of training required for a decent job in our society has been improving steadily since 1400, and particularly it has been accelerating during the latter part of this century. The other line shows the amount of useful work that the educational delivery system that we have had for the past 500 years is capable of producing. As you can see, the line representing the necessary training has begun to soar over the line representing what the current system can produce. Thus increasingly we are having a shortfall between the requirements for education and the ability of the delivery system to produce it.

Even more discouraging is the fact that the line representing the amount of effective instruction capable under the current delivery system has now flattened out, and no amount of additional money appears to be improving it (Chart 7). As a matter of fact, between 1950 and 1975, the investment in the educational delivery system more than doubled, and during this same period national scores sagged slightly. Restated in terms of the gross national product, between 1950 and 1975 the level of expenditure went from 3.4 percent to 7.4 percent.

We have learned in society that when we pour money into a delivery system and it does not produce more useful work, then we have hit natural system limits; or stated another way, the delivery system has matured. Put in terms of a more homey metaphor, the horse as a transportation delivery system is able to produce approximately 1 horsepower. If we whip the horse, feed it special diets, shod its feet with titanium, and aerodynamically work on the arrangement of its mane, then we still are not going to get much more than 1 horsepower out of it. If we insist on investing a great deal more money to try to get more than the 1 horsepower, then we are wasting our financial resources.

Thus the delivery system always sets the limits for the amount of useful work that can be produced. Moving from this abstract concept to a devastating statistic of its implications, I would note that the latest tests show that 42 percent of the 17-year-old blacks in America are functionally illiterate. We must look this statistic in the eye and face it without sentimental equivocation. What it says is that the current educational delivery system is failing. Furthermore, despite pouring more and more money into the system, we have been unable to improve the statistics.

Similarly, in New York City the reading scores are chilling. Forty-five percent of the high school population cannot read a simple paragraph for comprehension. An additional 23 percent can barely do so. Commenting on these and similar statistics, the executive director of the NAACP recently said, "What is to become of the black race in America?" Without functional basic literacy, a black student is going to have a difficult time finding work in a society that is increasingly turning to knowledge workers in its labor force.

As one sociologist commented, the dominant industry in the first third of the century was U.S. Steel; in the second third it was General

Motors; and in the last third it is IBM. The implications of this analogy are that the work force required for each of these industries has grown increasingly sophisticated in its capabilities. Put another way, if too many of our people are functionally illiterate, they cannot work successfully in our economy. Therefore, we are inevitably going to have an enormous inflationary drag on the economic system of our country as we must pay to support people who cannot work productively, or the fabric of society will be torn to pieces by those groups who are unable to make a satisfactory living wage.

The final point on Chart 7 shows another discouraging statistic suggesting Professor Herrnstein's analysis of the implications of the Coleman report. He has pointed out that in his opinion the implications of the Coleman report are that our educational delivery system, contrary to all public perception, is relatively equal in its treatment of its students.

In other words, try as you may, in researching any area of the country, you will have a difficult time finding inequality in any area that can be measured in terms of resources in the current delivery system. Thus the number of books available, the type of physical plant, the level of training for the faculty, the numbers of school days in the year, et cetera, are relatively equal.

The only things that turned out to not be equal are those things which we cannot purchase. Some of these are the perceptions of the children as to the importance of education as a function of the traditions they were raised in; or, similarly, their attitudes toward discipline and the values that they expect from their school experience.

The ultimate impact of the Coleman report was that it devastated educational leadership because it made pessimists out of many people. What it suggested is that if you have a relatively equal system, pouring money in is not going to affect things dramatically. The implications of the Coleman report have been borne out in the experience we have had in pouring money into the system since the Coleman research in 1964–66.

I would like to call our attention to an equation that can clarify my central points very quickly (Chart 8). The standard equation for discussing the amount of useful work that any delivery system can produce, be it transportation, communication, war, or education, is that the number of workers times the efficiency level that they can be trained to achieve equals the amount of useful work in the delivery system.

When a delivery system is static, people tend to work at raising more money to increase the number of workers, or conversely they work at schemes to make their training or productivity more efficient (Chart 9). In education, for example, foundations and governmental agencies have invested heavily in increasing the support for the number of workers by adding paraprofessionals; they have increased teacher training; they have worked at the physical plant to make the atmosphere more pleasant for the students; they worked on decentralizing education and scheduling; and they have even experimented with management-by-objective techniques to help increase the efficiency of the educational delivery system. The problem with all of these investments is that they do not touch the fundamental limit of the current delivery system, which is, how do we improve individual instruction beyond the current system limits which restrict it to $\frac{1}{360}$ of the day.

Thus you can add flourescent lights, incandescent lights, purple lights, special windows, no windows, laboratories with special equipment, auditoriums with television cameras, or very simple small rooms. But when you are all done, none of these things will affect the fundamental limit of the current educational delivery system.

This is a very important issue, and the listener must understand it totally (Chart 10). For example, if you say that a student is only getting 10 seconds per hour of individual instruction, and you decide to buy more workers in order to improve it, you will find that you have improved things very little. One study indicated this and showed that it went from 1 minutes a day to 1 minute and a few seconds after the teaching population was doubled by placing paraprofessionals in the classroom. Thus you have a fundamental system limit that cannot be transcended unless you go to absurd investment levels.

The public perception of the shortcomings of the schools is that we are having discipline problems, or we have forgotten our way and failed to keep the basics as the heart of the curriculum. In fact, we are not facing a moral problem, a discipline problem, or an example of national softness. What we are facing is a work problem. The amount of work that the delivery system can deliver as currently constituted is inadequate to the tasks that are now required for a more educated worker in our society.

The idea of hiring more workers is always a very tempting siren song. While headmaster of a private school in New York City, I once faced a situation where I desired to learn more about the students' individual learning profiles so that I could communicate more accurately to them and to their parents the nature of their latent abilities. In order to help me in my quest, I developed a learning research center in this tiny school. My resources, in retrospect, were extraordinary. For a student population of 500, I had 3 Ph. D.'s working fulltime in the learning research center, 25 parent volunteers, and 7 predoctoral fellows from Teachers College of Columbia University.

Nevertheless, the processing of these students took so much time that we could not even dent the problem of getting an accurate assessment on the students' abilities and communicating these to the teachers and parents. I soon found, to my chagrin, that what I was really facing was a work problem. The amount of work that that large population of professionals could produce was totally inadequate to the needs of the problem.

The next chart (Chart 11) discusses some key deficiencies in the current delivery system. Obviously there are many deficiencies that are not covered here, but these specific ones are mentioned because they represent weaknesses of the delivery system that can be overcome by the judicious use of technology.

In addition to the first point which we have now discussed at length, the delivery system has a difficult time in assessing the learner profile of the students. When we attempt to get a more accurate picture of how a student really learns as a learner or what his or her specific learner attributes might be, we find this is too severe a work problem—as I just described in my attempt to produce a learning research center at the school I directed. Because of this work limitation, we are unable to test students adequately to understand their unique learner profile or to communicate whatever data we do have to the student, other faculty members, and the family. And what is even worse, even if we were able to assess information about true individual differences, we still have to treat students almost identically in groups of 25 to 30 within the system because of the work limitation of the teachers.

We have already mentioned earlier the difficulty of having the spread of learning abilities throughout an instructional unit of 25 to 30 students. By definition, this spread insures that much of the material that a student is subjected to is inappropriate for his or her needs or interests.

Obviously, with appropriate technology in the form of student work stations, a great deal of additional work can be generated by harnessing the power of the computer to do work in helping to alleviate these delivery system limitations. There are other attributes to having a private work station, however, which also improve a serious weakness of the delivery system. The exposure of a student to a public learning situation every time he is faced with a specific learning trial in the form of faculty questions or peer comments can have a very devastating psychological affect on learners which stops them from becoming active participants in the learning process. Faculty tend to miss this point in a classroom situation because in response to generalized questions to the class they tend to be rewarded with a sea of waving hands requesting permission to give the answer.

I once photographed a set of classroom dynamics to show the teacher what was really happening. In the first slide the teacher asked the question, in the second slide about 7 or 8 of the students from the section raised their hands and aggressively sought the teacher's attention. But I pointed out to the teacher that two-thirds of the class was not trying to get her attention, and in fact, quite a few of the students, were ducking their heads to avoid eye contact or the possibility of being called upon. Two or three of the students having the most difficulty were actually raising their arms and ducking their heads under them as if to ward off a blow. These students were not only fleeing from active trials in a learning situation, but were publicly exposed to the possibility of ridicule or public embarrassment every day of the school year.

We must never underestimate the power of social embarrassment in public learning situations or interactions. Even at the age of 48, I can recite to you almost every case from my educational history where someone laughed because of something I said in a classroom setting. I'm sure all of you had similar experiences. The irony of this problem is that the people who need the help the most in the classroom (those having the most learning difficulties) do not want to expose themselves to further public ridicule and hence do everything they can to avoid any learning trials. Distributed work stations which allow a student to sit privately at a terminal and try to master a process over and over until the point where achieving is consummated is ideal for this type of student.

Another weakness of the current delivery system is the way it restricts learning to a single location, the classroom. If we were able to distribute meaningful instructional interaction on a personalized level to the home instead of just the school, or to other areas of the school such as libraries and resource centers, then we could improve dramatically the 10-second-per-hour limitation of personal interactive instruction.

One of the great ironies of education is that an enormous percentage of the materials that the students struggle to learn will shortly be forgotten because of the learning decay problem. Because there is nothing that we can do about this, the delivery system as it is now constituted tends to ignore the issue. Once June comes and the students are released, the teachers no longer feel responsible for seeing that they are refreshed with additional trials lest they forget the materials. This is not a criticism, but a simple fact of the limits of the delivery system.

A closely related one is that of updating the students with the latest information. Once a student leaves the school classroom situation, the school no longer feels responsible for updating the alumnus on the latest materials because it would simply be too great a work problem. With the introduction of distributed work stations in the future, we will be able to offer refreshment at critical times for students who are about to enter a severe learning decay sequence. Thus the computer program will be able to calculate, based on individual learning profile information, when a learner will begin to forget some fundamental concepts that have been taught.

By offering the capability to automatically refresh at these key times, the distributed work station will keep the learned concepts alive in the student with just a tiny fraction of the time that it would take if the student allowed the decay to continue for too long a period. Similarly, students will be able to be updated automatically when new information supersedes data that were taught earlier.

Finally, the current delivery system suffers from an extraordinary lack of instructional consistency on the part of the teacher. Teachers are human and have the same cycles of boredom and stress as all other individuals, and as a result, they tend to teach according to current moods or interests rather than to say the same thing day after day in a consistent fashion to the students. One of the great advantages of technology is that it can offer perfect consistency day after day to students who are trying to learn the procedures, algorithms, and terminology associated with complicated learning experiences.

Chart 12 illustrates the appropriate equation for analyzing a delivery system, any delivery system. As you can see in comparing this with the earlier equation, I have added another box entitled "system technology factor." What this equation indicates is that there is another factor which provides the greatest potential leverage in most delivery systems; the system technology factor. For example, if we were discussing transportation systems, and we were using the horse as our example of the work component of the delivery system, then the system technology factor would be 1, representing 1 horsepower. This assumes that I have one worker who has been trained to an efficiency of 100 percent.

If I train another worker in the use of the car, however, I now have a new system technology factor of approximately 300. And if I were training another individual to fly a jet aircraft, a system technology factor would probably be 30,000 or so.

Thus, the real multiple, or leverage, comes from the system technology factor. The implications of this for our presentation today are that if indeed we are starved for adequate work in our educational delivery system because the teacher can only work on an individual basis with the student for an average of 10 seconds out of every hour, then the way to solve this problem is to use a much higher system technology factor that will allow us to produce exponentially more work to give the student his individualized interactions.

It is important to understand that once a delivery system matures, that the only way we can produce the additional requisite work in that delivery system is by introducing a new system technology factor. An interesting thought is that probably the speed of light, since it is the fastest known thing in the universe, is probably the ultimate technology factor. Once you can harness the speed of light as your technology factor, then there is no contest with any other delivery system.

For example, if I wanted to send a message from my New York office to my Utah office by "Pony Express," the horse would not have traveled more than a few feet before I would have completed the message by using the speed of light as an alternate delivery system. Most people are not aware that the "Pony Express" ceased operating 1 week after the connection of the first coast to coast telegraph.

Thus, when you can use a technology factor that gets close to the speed of light, you have reached the theoretical maximum in terms of what a delivery system can do. This is precisely what a computer does. When we use a computer, we are harnessing something close to the speed of light as we use electricity to generate useful instructions in the computer. After 15 years of careful research, we have discovered that the work bonus that the computer brings can be used in a number of useful ways. The task in the decade ahead will be to help harness the exponentially greater amount of work that the computer can generate for the educational delivery system in a useful way that will help children and faculty members complete their educational tasks successfully in an atmosphere that is pleasant.

Chart 13 expresses the practical implications of this equation as elaborated on a graph. What this graph indicates is that the proper introduction of technology will allow far more work to be done by the educational delivery system. This in turn will improve the effectiveness of the delivery system, particularly through giving the individual the opportunity to have far more individual instruction, and raise the effectiveness of the educational delivery system to a level that is more than required for training potential workers or students in the future.

Chart 14 elaborates the two most fundamental technologies of the future that I would like to call your attention to. The first is the computer. The computer's power is needed because—and I hesitate to use the word here because it has strong connotations that sometimes upset people—it can produce the type of artificial intelligence distributed locally to the student and interact with him on a personal basis. In other words, you are going to be able to distribute a type of processing or artificial intelligence to the work station level that can interact with the student. I must point out unequivocally that if we attempt to use technology without the computer, we are going to have an extremely limited impact because in the absence of processing or artificial intelligence that a computer can carry, the delivery system is unable to increase the kind of interactivity—through trials and feedback and simulation—that the student needs to increase his learner productivity.

Note that if a child has access to a teacher talking to him, but cannot ask the teacher questions or be asked questions by the teacher because of system constraints, then he is restricted in terms of the number of meaningful trials and personal activity that he can become involved in. Thus, replicating the teacher by putting them on television or placing him on a movie or slide tape, accomplishes very little for the student. He is still a passive observer—he is still watching someone else, and he still gets anything from zero to 1/360 of his time at a maximum in a situation where he has individual interactive instruction.

Thus, no matter how we launch more satellites, better satellites, more profound satellites, or friendly satellites, we are not going to change anything in terms of producing television for the general population that will have any impact. This is because television never has, or never will be able to accomplish a significant individual interactive situation with the student.

One of the greatest problems that educational reformers have had in using technology is that they have been indiscriminate in their use of it without understanding that only one or two of the technologies can make any fundamental difference. All technologies are not the same, and unless the computer is present, with the type of distributed or artificial intelligence that can give the personal interactive situation to the student, then very little improvement can be given to the delivery system. I do not have time here to discuss the many ways that the computer's distributed intelligence can be used, but it is important to understand that it must be present if any fundamental change is to take place in the delivery system.

The second new fundamental technology is the laser. It too is a derivative of light, but it is being used in a special application that will allow the amounts of information that can be stored to improve rather dramatically. In its most obvious format, the laser will be used with videodisc to store a great deal of information for student instruction. It not only can produce more information, but also has a much more interesting format than a computer can generate. Thus, it can involve color, movies, sound, motion, and a type of personal identification with thought, character, and situation that humans enjoy in watching movies or drama.

In the videodisc, the laser is used as a stylus, much as a phonograph uses a needle. But since it is made of light and can produce such a fine point, it does not wear anything out on the record and can access an extraordinary amount of information. This allows a videodisc player to pull in any one of 54,000 color photographs from one side of a videodisc and hold it permanently on the color television screen as it replays the same groove 30 times a second without wearing it out. The National Science Foundation has been deeply involved in working on using these new technologies with a number of programs, and there is little question that the combination of the microcomputer and the videodisc will be the ideal instructional format of the future.

Chart 15 is really an engineering chart to help explain to you some of the technological forces that will be producing the technologies of the future for us in a very economical fashion. What the graph indicates is that the number of transistors that can be placed on a small chip which is less than your small finger now has doubled every year since 1960. As in the case of mathematics, the doubling phenomenon is not particularly very interesting at first. First, it goes two, then four, then eight, et cetera. But toward the end of the doubling cycle, the numbers get enormous. Sometime during 1980, laboratories will be producing prototype chips with 1 million transistors on them. Semiconductor experts generally agree that the doubling should begin to slow down after 1980 to every 1½ or 2 years instead of every year. Nevertheless, the practical implications of this diagram are that by 1985 or 1986, we will begin to manufacture chips that have the equivalent of a powerful IBM 370 computer on them with 1 million bits of memory, all on the same chip. Preliminary estimations are also that thees chips should sell in wholesale quantities in the neighborhood of $100.

One of the reasons that I was attracted to work with computers is that I stumbled across an earlier version of this chart in the late 1960's. I did not believe it, and at first did not pay very much attention to it. I have a Ph. D. in English and have never been formally trained as a technologist. I was so irritated, offended, and attracted by this extraordinary graph that I began to follow the field and to study the literature to see if it really were true. After a number of years of intensive study and observation, I learned that the curves were coming true, and as a resultI left my profession of running a school to prepare for the onslaught of these devices.

The cost of these chips is astonishing because in high volume, manufacturers are able to make them for as little as $3 to $4. When a new chip first comes out, it is usually quite expensive, but within a couple of years if it succeeds in achieving high volume, the price drops to this low level. We are building a computer memory which uses chips with 4,000 bits of memory on them that cost us $4 apiece. We are also ordering the newer chips which have 16,000 bits of memory on them because the price has recently declined to the $4 range also. Thus, for the same dollar value, I now have four times the memory power. We are also purchasing the newer chips in prototype quantities for $50 to $100 that have 64,000 bits of memory on them. Within a couple of years their price also will have fallen to the $4 range.

Chart 16 indicates how these transistors will be used to produce various memory and computer devices. You can see that shortly after 1970, the one-chip calculator was produced, and that by 1980 a 16-bit microprocessor and the 64,000 bit RAM memory were commercial products. The next predicted commercial product that will have a strong difference will be the start of adding to the 16-bit microcomputer 32,000 bits of memory on the same chip. And then sometime by the mid-1980's or latter part of the decade, we will have the 32-bit microprocessor with 1 million bits of memory all on the same small chip.

Chart 17 discusses the declining cost of memory. You do not have to be an expert to see that this is one of the few areas in our society where all the cost lines are declining rather dramatically.

In terms of educational usage, the practical implications of these three charts are that the work stations that we manufacture for students in schools, and ultimately even in the home, will soon reach a level where the expense is not prohibitive. This is an important ingredient in attempting to produce a useful market for work stations for the schools. Practically speaking, in 1965 it cost $50,000 for one work station for a student. The work station itself did not cost $50,000, but if a computer was $300,000 and it could support only six terminals on it, then in effect the cost per work station was $50,000. Ten years later in 1975, the work station had dropped one order of magnitude to a price of $5,000. Ten years after that, in the 1985 range, we estimate that work stations will be in the $500 to $1,000 range. Thus, we can see that technologically the stage is set for the delivery of economic work stations to both school and the home markets to give the students the additional work potential with distributed intelligence present.

Now I would like to turn to discuss how we are going to use this new distributed power, this new ability to do work with an improved delivery system, in the decade ahead. Clearly, we have 15 to 20 years, worth of research that's been done by some outstanding pioneers. Many of them have spent months and even years at terminals, staying up half the night to code machines that were ornery, to say the least. As I look throughout this audience I see many old friends and experts who worked hard to use this new technology.

As Chart 18 indicates, we know at least seven ways we will be able to use this new power to improve the delivery system. At least the first two items, that is computer-managed instruction—CMI—and drill and practice, have already had a modest degree of success.

Chart 19 discusses the first task, CMI, in greater detail. Computer-managed instruction is an important attribute not only because it helps teachers manage the instructional flow better, but also because it diffuses their anxieties about computers while it helps them with difficult bookkeeping chores. Contrary to general wisdom, not all of the early efforts to sell computers to schools were failures. One man who was particularly successful was Harvey Brudner, who ran Westinghouse Learning. He was very successful in writing excellent computer-manged instruction packages for teachers and learned to market them to the school systems. Most of the early systems that are going out on the home computers to the school systems are also including computer-managed instruction packages in order to attract the teacher's attention by offering a genuine service in an area that can be drudgery for the faculty member.

Some of the qualities of computer-manged instruction are the ability to give pre- and post-tests, offer diagnostics, help the students with assignments, keep student records for the classroom teacher in the school, and to assure competency-based performance. We are now working on programs, for example, that will test the student to see how he or she understands elementary school mathematics topics. One program we have developed has over 2,000 test items which can discover to a finely tuned degree how knowledgeable a student is in any of the elementary school mathematics topics. Having discovered the students' proficiency, the program then makes assignments to the student by textbook, title, and page number for those textual materials that are available as a resource in that particular classroom. Thus, the teacher has a great deal of work being done for him or her without having to be present to do all the testing, assigning, and recordkeeping.

Using computer-managed instruction is an excellent way to begin the introduction of computers into the school system. Since the computer is not involved in teaching with these programs, the teacher does not feel threatened initially by having the computer a part of the educational process.

Chart 20 discusses a second contribution that computers can make through the administering of drill and practice materials. Patrick Suppes of Stanford University, with the help of the National Science Foundation, the National Institute of Education, and various governmental agencies and foundations was able to develop some outstanding drill and practice materials during the late 1960's. His research showed us how to arrange and administer drill and practice sessions in mathematics, in particular, for students. Although the programs look deceptively simple, there is really a great deal of distributed processing or artificial intelligence present in these programs.

First the computer has to look up and generate questions that are appropriate to the students' current level of competence, then calculate whether or not their response is appropriate, and take action if it is not. Furthermore, it has to monitor the progress of the student and change the level of difficulty of the programs if they are becoming too easy or too hard for the student. Then the program also keeps records and produces patterns so that teachers and administrators can study exactly what the student is doing in terms of useful educational work.

On one site visit where I had a 16-terminal room, I had a class of 20 students working in the room. Sixteen students who worked on the terminals were getting many trials with feedback per minute, while the four students who were left out were assigned to do their drill and practice work on paper and pencil. Within a few moments, they were all standing in a line to talk to the teacher to see how they were doing on their drill and practice programs, and as a result, most of the period was a waste for them in terms of useful learner productivity.

This approach is not a panacea, and in fact has some distinct problems. The most critical one is that if the student does not know the answer, then the program can only say "No, try again," or finally give the answer if the student continues to miss. This leads to Chart 21 which discusses the concept of helps. Helps take the level of contribution of the work station up a whole level by helping the students learn how to solve a problem that he or she cannot do. Helps can be broken into two categories, general helps and specific helps. In a general help, if a student missed a specific math problem and didn't know how to do it, then he or she could call in a help which explained how to do a problem similar to the type that he had missed. A specific help is even more useful because it recalls the very problem that the student has been unable to solve and then systematically breaks down the arithmetic operations and shows the student how to solve that very problem. By 1981, a few publishers will begin to distribute some materials, primarily in mathematics, which have these first three capabilities, that is, CMI, drill and practice, and the use of specific helps.

Chart 22 discusses a fourth level of contribution that the new technology can offer to the delivery system. In the first three uses, there was an assumption that the teacher had taught the student the educational concepts, and the computer was being used to help solidify the concepts or remind the student of what they were. Inevitably, however, different students in any section will want to move ahead of the pace that the class is setting and would like to have an opportunity to learn things individually when the teacher was not available.

Thus, the next level of general contribution will be the development of full instructional programs that can supplement the teacher's efforts when he or she is tied up in a classroom setting. Coupling a videodisc to a microprocessor will probably be an ideal instrument for this type of instruction. But just as the faster students will be served by not being held back when they desire to go on further, so also will the slower students be served by being able to go back and review an instructional process that they are falling behind on. Thus, having these materials available gives a teacher an inherent advantage because the class will be able to learn the materials according to their own individual needs.

Chart 23 suggests the direction that we will be taking over the next few years in work on cognitive diagnostics. An example of why a cognitive diagnostic will be useful is as follows:

$$\begin{array}{r} 127 \\ -90 \\ \hline 170 \end{array}$$

This might be a typical error or set of errors that a student makes in doing a subtraction problem. There have been over 60 deep cognitive errors identified, informally labeled "bugs", that students have when doing the subtraction operation. A normal person viewing this problem, or perhaps a harried teacher who is grading hundreds of them at home at night, might say, "How in the world does that child get 170 for an answer when they are taking 90 from 127?"

In actual fact, the student is following a very logical algorithm that happens to be wrong. When subtracting 0 from 7, he has made the answer 0 instead of 7. He thinks that whenever a 0 appears, that whenever it gets involved with another number, it always produces another zero. This is certainly true in the multiplication process, but not in subtraction. Nevertheless, it's a very logical error that a learning student makes very frequently. We call this a zero bug. He also suffers from another deep cognitive error called the "lesser than greater" bug. Since he is working on a subtraction problem, he cannot imagine subtracting a larger number from a smaller number. so whenever he sees two numbers involved in subtraction, he always subtracts the smaller from the larger number. In this case, he is taking 2 from 9 and making it a seven.

The theoretical implications of this problem are most significant. A normal teacher will not be able to identify, much less have time, to discuss the 60 or so cognitive errors a student can make in subtraction. In fact, since approximately one-fifth of the time in elementary school is spent in mathematical studies, the student will probably have no more than 2 seconds per hour available for individual interactive instruction in mathematics with the teacher.

The example is not always theoretical, however, I have a daughter named Hilary, who was in the third grade, and had a zero bug for

7 weeks before the local school system was able to identify her problem. At the time this happened, she had a warm, loving teacher, who had a class of 30 students. The teacher attempted to individualize the instruction by having the students work in different books at different ability levels. At the conclusion of one of the segments of an individual program, the teacher would then have the student take a test. Because the teacher was so pressed for time to spend on individual attention, as our statistics have clearly shown, she designed a system that allowed the student to take a test at the end, and if she failed, she would redo the book that they were working on. After the student failed the test for the third time, the teacher would realize that there was some fundamental problem that deserved attention.

At this point she would study the diagnostics carefully, discover the cognitive error, and then work at length with the student to explain the problem. In having this long personal session with the student, the teacher would use up the student's share—1[illegible] seconds a day—of time that they would have available on an individual basis with the teacher. This meant that the teacher was not available to work with that student at any length until some future crisis produced a similar problem.

The advantage of a computer work station is that carefully programed diagnostic programs could establish that Hilary had a zero bug within seconds, instead of 7 weeks, and remediate instantaneously while she was working on the terminal that very day. This is how we will be using these small chips that do a few million instructions a second in the future in this area of cognitive research.

In Chart 24, I am dicussing an even higher level of computer usage that will harness the power of the chips to do simulation and games. Simulation learning is extremely important because it uses artificial intelligence to allow a student to have a personal learning experience where they use what scholars have called "discovery learning" strategies. In other words a program is developed which allows a student to take various courses of action, and the power of the computer is used to calculate the implications of that action. Thus, students can try various options to see what would happen if they took a specific set of decisions. Here they begin to explore the world on their own and be able to branch out and experiment with numerous variables to discover the patterns and laws that govern both the social and scientific environments.

At this level, games can also be introduced as a part of the curriculum which can provide relief and harness the natural competitive instinct of many of the students. These games can be carefully designed to insure that a significant learning experience is part of the process. In the future we will probably have various types of games introduced at regular sequences in the curriculum so that the students can have some relief from straight learning situations and be given an opportunity to manipulate the concepts under a fresh viewpoint.

The advantages of simulations are that you can set up outstanding experimental opportunities for the students where experiments might be too dangerous to perform in normal society. This danger could be of the laboratory type, or of actually dealing in a political way with the population. When most students are given an opportunity to direct the Nation, they quickly kill off the population through a series of blunders in the way they allocate their resources. Similarly, most students find it extremely difficult to be an elected official and deal with the multiple types of pressure that these officeholders face. The advantage of introducing young students to these types of complicated situations is that they soon lose simplistic attitudes toward complex areas. This is particularly noteworthy when you consider that many people never have an opportunity to experience this kind of complexity in a leadership or decisionmaking role until they are in their forties or fifties.

Chart 25 discusses the highest level of future usage for the computer which will have to do with research on the learner profile of the individual students. One use of these programs will be to establish how a student is learning as a learner, and then to convey to him or her the implications of their approach. Another use is to establish quite clearly the type of learning characteristic that that student has through genetic means. Some students who have dyslexia have severely twisted internal circuitry that does not allow them to view an O without seeing a C. It is important that we have outstanding diagnostics programs which can pick up learning disabilities when students are very young so that remediation can be effected. In fact, probably the computer will be an ideal patient source of remediation for many forms of learning disability.

But even more importantly, this type of information will be very useful for students and parents in helping to understand the apparent strengths and weaknesses of the learner profile of the individual student. In a very pragmatic way, this should help relieve unnecessary guilt over certain types of learning problems, and it should heighten an understanding of where the strengths lay so that the students just do not feel that they are not very bright. The type of measurement that will be able to be done by sophisticated programs will allow us to go far beyond the standard simple measurements done in the IQ and SAT type tests. This means we will be able to develop an accurate picture of strengths which are sometimes nontraditional that will give the student a greater sense of being and to clear a perception, perhaps, of how his or her talents might be used in productive careers in the future.

At the present time, very little is being done in terms of establishing this type of factual material in a school because of the work problem. Since not a great deal is done or talked about, students tend to think that they learn like everyone else learns. Nothing could be farther from the truth. Furthermore, we do not even have a vocabulary to talk to students about their apparent strengths and weaknesses and some of the more profound implications of these. For example, I once taught a student with 100 percent audio retention who seemed to be blessed with extraordinary talents. Unfortunately, her retention kept her from learning how to sort the material into usable segments and how to discard information that was not relevant to a current situation.

Chart 26 discusses the participants which must be kept in mind when we introduce this new technology to the schools and homes. No simple solution which ignores any of these components—the publishers, hardware manufacturers, schools, foundations, and government—will have a lasting impact on the educational culture.

Chart 27 reviews some of the problems of the first 20 years and suggests what we should be careful about in future developmental efforts. First of all, we should understand that the political climate for introducing technology into school systems is very poor. This is primarily because of the residue of the early efforts in the 1960's when the hardware manufacturers and the publishers lost millions of dollars attempting a premature entry when the work stations were too expensive. Many of the people who led the early efforts in the 1960's feel that they are much wiser now in the 1980 climate, and they are determined never to try again. Since as much as 20 years has passed for some of these people, many of them are in their fifties or sixties and in influential decisionmaking positions. Furthermore, we have not exactly made those people who backed these early research efforts feel as if their efforts were appreciated. There has been much criticism of the PLATO and TICCIT projects, for example; whereas, in reality they have made a stunning contribution in advancing the entire field.

A deeper problem is the national planning characteristics of Americans. In America, we want to solve all our problems in 1- to 3-year cycles. Funding is traditionally given at this level, and even if problems are beginning to become 10- to 20-year problems, they only receive a 3-year funding cycle before an announcement is made that they are a failure. The Government is the one segment of the society which should have the sagacity to develop longer range programs that are funded consistently to allow solutions to be generated and opportunities to be taken in these new technological areas. Most of the great pioneers of the 1960's and 1970's have been splintered by the funding patterns, and work of any significance has almost crawled to a halt because of the stop-start nature of the funding process; 10- and 20-year problems need 10- and 20-year funding cycles.

Arthur Melmed referred to the next point in his talk before mine when he stressed that some of the hardware is beginning to outstrip the software and curriculum development. At least 100,000 home computers have been sold to various schools and colleges as of this date, and there is almost no usable software for them of any consequence. For a decade, many scholars have been warning the Government that this problem would happen, and now that it is upon us, we are still in planning sessions instead of attempting to directly fund software development before the hardware is totally out of hand.

One of the problems of not adequately funding the software early enough is that many commercial interests now smell the possibility for some quick profits because of all the terminals appearing in position. As a result, they are beginning to develop some very, very poor materials to get them out as quick as possible to make a fast dollar. This can lead to a rather severe backlash from the user community who will think that this type of software is all that a computer can do. Thus, the leadership must help insure that we get some outstanding materials developed which can serve as models for other developmental projects in the years ahead.

Chart 28 attempts to take head-on the really central problem of implementation in the future—the inhumane metaphor that is conjured up by the use of technology in education with children. It is quite common, for example, to attack computer terminals because when children work on them, they work in social isolation without any human contact. There is a definite feeling that this is not healthy for the personality and that interacting with technology in isolation is an inhumane activity. The problem with responding to this type of criticism is that it is quite emotional and not very thoughtful. For example, the social interaction that I have described also fits reading the book. In fact, the book is a product of an earlier educational technology, the printing press. Furthermore, when the printing press was invented and books were first printed for educational purposes, there was a great human cry about the same subject. Nevertheless, we have grown to love books and revere them, and even build our great universities around libraries because we feel such respect for book materials.

A second problem is that we always attack a new approach for inhumane reasons without ever stopping to consider about how inhumane the current system is. There is nothing inherently humane in having 42 percent of the black 17-year-olds in this country functionally illiterate. If the current delivery system were totally humane, then we would not be full of concern about what it is doing to our students. Thus the new must not always bear the brunt of the cry of being inhumane, and the old must also face the implications of this position as well.

Finally, I would like to stress unequivocally that computers will not replace the teacher. In fact, they will enhance the role of the teacher by freeing the teacher to deal on a more personal level—a more humane level if you will—with the students. The computer will pick up the more difficult chores which the teacher has always felt have interfered with serious learning. They will do the record keeping, the drill and practice, the helps with the standard misunderstandings. In conclusion, I would note again that I started this talk by showing you the great humane metaphor of the teacher leaning over a student on a 1-to-1 relationship which I now hope you realize is a very rare occurrence in an educational system. Thus, we must understand that there is nothing inherently inhumane about technology, that it will not replace the teacher and the teacher's human values, and that in fact it will produce a much more humane product and allow the teacher a more humane role in future educational delivery systems.

I will close with that. Thank you very much.

[Applause.]

[The charts used by Dr. Dustin Heuston to illustrate his testimony follow:]

Chart
①

The Dominant Metaphor
of Education

The dominant metaphor in education is that of a teacher working at a close relationship of an individual student where the needs of the student are being met by a sympathetic adult.

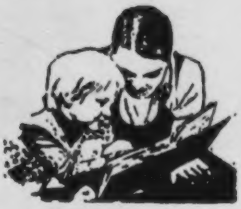
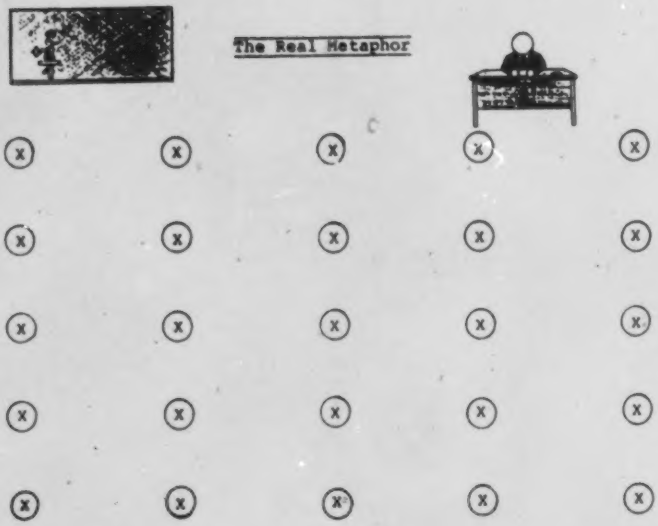
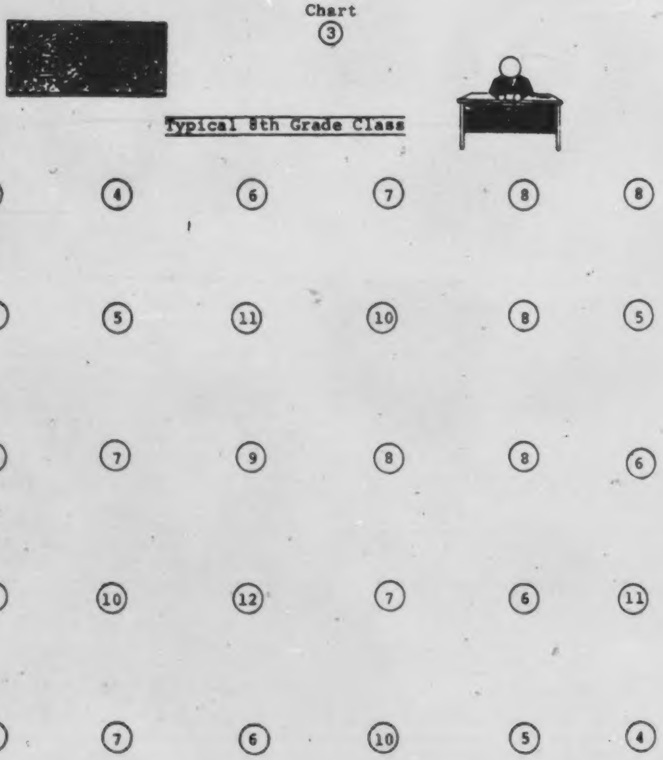


Chart
②



In truth, the real metaphor should be one of a teacher in front of a class of 30 students with all of the inherent problems of trying to interact personally with those 30 students.

Chart ③


Typical 8th Grade Class
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4

A good rule of thumb for elementary school education is that the class will have as many years of student difference in ability within a single section as the level of that class. In other words, by the eighth grade, there are eight years of student ability within a given section. Typically, the grade level abilities of the students in the class might range from the fourth through the twelfth grade. This diagram suggests what the individual student grade level differences might be in a typical section.

Chart
④

Actual Facts

10 seconds of individual
instruction or help for
every hour a learner
spends in school

10 seconds	vs	1 hour

1/360

Two large studies by Conant and Christiansen have shown that a normal student cannot average more than one minute a day of individual instruction or attention from a faculty member. This breaks down on an hourly basis to ten seconds out of every hour that the student puts in in school. Stated in terms of a ratio, this means that 1/360th of a students time in school is spent in an individual instruction mode. In terms of the school year, this means that a student has individual instruction for only one half of one school day.

Chart
⑤

Implication of Time Limitation

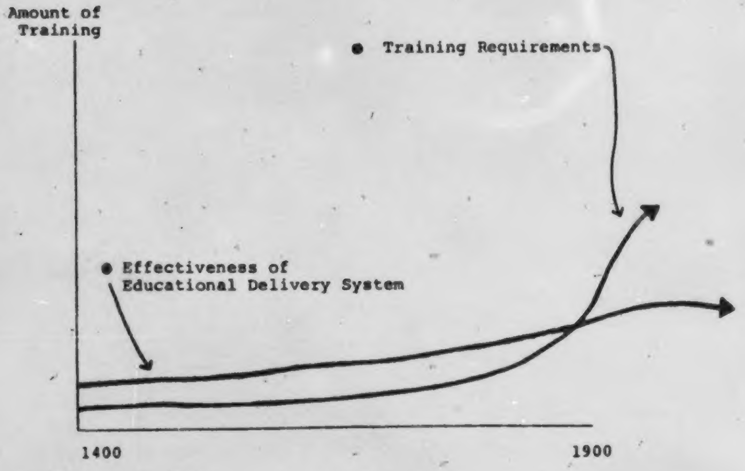
- Unless these limits are addressed, education will not improve further.
- Only technology can solve this problem.

The purpose of these two points is to suggest that no matter what the good intentions are of sponsoring parties for improving the school system, unless this basic limitation of having the student get access to individual instruction for only a few seconds per hour of effort, the school system cannot really improve further. Furthermore, the only way to provide the additional work necessary to provide the individual instruction is through the judicious use of technology.

As jolting as these two statements might appear, they must be faced in order to have improvement. There simply are no other alternatives; although, to date, there have been many tried.

Chart
⑥

Educational Delivery System Problem



The purpose of this graph is to indicate how the need for training and education has continued to rise for the past few centuries because of the impact of technology. The work force must be able to handle more complicated and sophisticated job skills with each increasing decade. Unfortunately, the limits of the current educational delivery system appear to have been reached. Every delivery system has a fixed work limit. When a delivery system reaches this limit, it can be said to be mature. One of the symptoms of a mature delivery system is the addition of new investment to that delivery system will not substantially change the amount of work that it can produce. No matter how much money is invested, it would be difficult to have a horse produce more than one horsepower.

Chart
⑦

Data Suggest Additional Financial Investment is Wasted Capital

- 1950 - 1975 Educational Expenditure increased from 3.4 percent to 7.4 percent of Gross National Product, an increase of 118 percent.
- National scores declined slightly after this increased investment.
- 42 percent of 17 year old Blacks are functionally illiterate.
- Coleman Report corroborated that Delivery System has matured.

Chart
⑧

Standard Training Algorithm
Assumes Static Delivery System
Past 500 Years

Number of Workers x Training Efficiency = Total Useful Work

The standard training or educational algorithms that people carry in their head can be expressed in an equation. They assume that to the extent they train their workers (in this case the teacher) they will be able to produce work adequate to the task. The problem that must be faced, however, is that there are many occasions where the number of workers trained as well as possible still will not be able to do enough work to solve serious problems.

Chart
⑨

Standard Solutions
Assuming Static Delivery System

Invest More Capital in Improving Various Components of System

- Scheduling
- Curricula
- Management
- Instructional design
- Testing and Evaluation
- Individualization
- Instructor Training
- Physical Plant

Instead of facing the implications of the limits of that equation, people who are responsible for improving the educational system have expanded their efforts to include a host of auxiliary items. Unfortunately, none of these can get at the fundamental problem which is the work limit of the current educational delivery system.

Chart
⑩

The Key Issue

- None of the Delivery System Limitations is Even Marginally Improved by Substantial Increases in Investment
- For Example: Adding a Second Instructor to a Class for Half a Day
  (Increasing Staff Investment by 50 Percent) Only increases Learner Access Time to Interactive, Personalized Instruction from One Minute a Day to One Minute and a Few Seconds a Day

Chart
⑪

Current Delivery System Limits

- Minute a Day Access to Interactive, Personalized Instruction (10 Seconds Per Hour)
- Learner Assessment
- Spread of Learner Abilities in Instructional Unit
- Public Learning
- Location Limitations
- Refreshment
- Updating
- Instructional Consistency

Chart
⑫

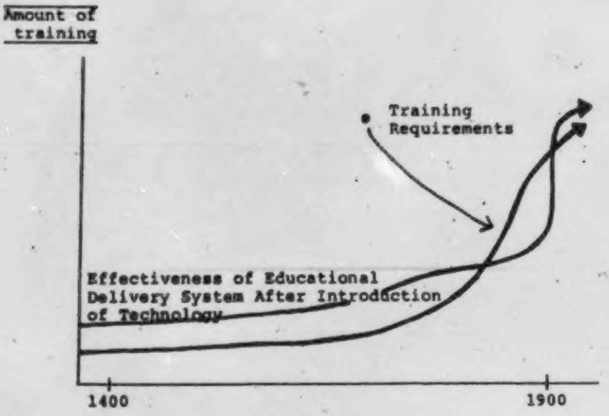
MORE ACCURATE ALGORITHM OF THE SOURCES OF WORK IN A DELIVERY SYSTEM

$$\boxed{\text{Number of Workers}} \times \boxed{\text{Training Efficiency}} \times \boxed{\text{System Technology Factor}} = \boxed{\text{Total Useful Work}}$$

What this equation indicates is that there is another factor which provides the greatest leverage of all in most delivery systems: the system technology factor. For example, if we were discussing transportation systems, and we were using the horse, then the system technology factor would be one, representing one horsepower. If it were a car, however, the multiple would probably be close to 300, representing 300 horsepower of an automobile engine. If we were substituting the jet aircraft, then the system technology factor might be a multiple of 30,000, representing 30,000 horsepower. Please notice that no amount of improving of a worker through training efficiency can change the fundamental mature limits of any delivery system. The same is true of the educational delivery system.

Chart
⑬

New Educational Delivery System



What this indicates is that the proper introduction of technology will allow far more work to be done by the educational delivery system. This in turn will improve the effectiveness of the delivery system, particularly by giving the individual the opportunity to have far more individual instruction, and raise the effectiveness of the educational delivery system to a level that is more than the requirement for training potential workers.

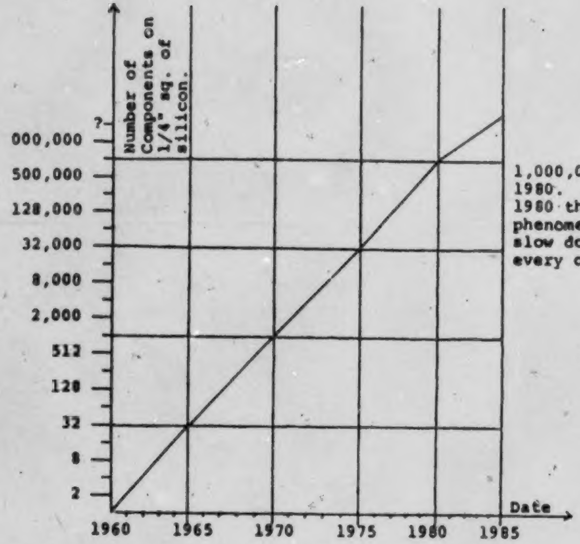
Chart
⑭

The Two Fundamental Technologies

- Must have computer
  - Random access
  - Processing intelligence
- Must have laser
  - Amount of information
  - More interesting format
  - Friction free stylus

Chart
⑮

Numbers of Transistors on a Single Chip

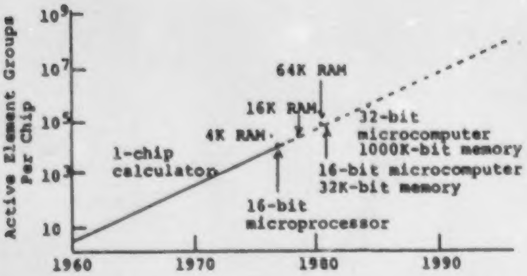


1,000,000 by 1980. After 1980 the doubling phenomenon will slow down to every other year.

What this graph illustrates is that every year since 1960 the number of electronic components that can be placed on a piece of silicon approximately ¼" square has doubled. Semiconductor experts generally agree that this doubling should continue through 1980 when the process should start to slow down to a doubling every two years and continue on to the 1980's. Stated pragmatically, this means that sometime after the mid 1980's that microcomputers with the power of an IBM 370 will be placed with one million bits of memory, and the chip will wholesale for a cost of less than $100.

Chart
⑯

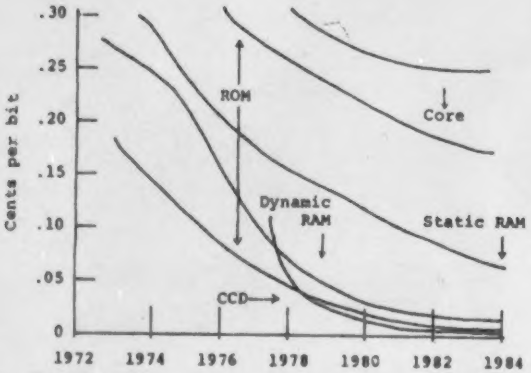
Chip Configuration



To give a sense of past, present, and future capabilities of the chips, the above diagram is offered.

Chart ⑰

Declining Cost of Memory



These technical graphs of various types of memory costs are illustrated only to make the point that the cost of memory is declining dramatically, and one need not be a technician to gain this message. In contrast to the dramatically rising cost of almost everything else in society, it is not difficult to see that the costs of technologies will be far less than other additions to the educational training system.

Chart
⑱

Seven Levels of Contribution by Technology

1. CMI
2. Drill and Practice
3. Helps
4. Cognitive Diagnostics
5. Instruction
6. Simulation (Games)
7. Learner Profile

These seven levels are listed in order to show the practical implications of the technology as they will be introduced throughout the educational delivery system.

Chart
⑲

Computer Managed Instruction

- Pre and Post Test
- Diagnostics
- Assignments
- Student Records
- Competency Based

Chart ⑳

Drill & Practice

- Trial with Instant Feedback
- Floating Norms
- Private Practice
- Solidify Intermittent Understanding
- Will Not Surmount Ignorance

Chart ㉑

HELPS

- General
- Specific

Chart ㉒

Instruction

- Allow student to advance without waiting
- Help slower students with repetition
- Allow rapid access to explanations of total process

Chart
㉓

Cognitive Diagnostics

$$\begin{array}{r} 127 \\ \underline{-90} \\ 170 \end{array}$$

Over 60 subraction cognitive errors

This subtraction problem is shown as an example of how a student can make what appears to be a very silly error to an observer; whereas, in actual fact, the student is following a rigorous algorithm that has some flaws. He suffers from a cognitive error which is called the zero "bug". When he has subtracted zero from seven, he has made the answer zero instead of seven. He also suffers from another cognitive error called the "lesser than greater". He has taken the smaller number two from the larger nine instead of trying to subtract nine from twelve.

The implications of this problem are most significant. A normal teacher will not be able to identify, much less have time, to discuss the sixty or so cognitive errors a student can make in subtraction. In fact, since approximately one-fifth of the time in elementary school is spent in mathmatical studies, the student is entitled to approximately two seconds of individual instruction in mathematics per hour that he or she puts in. A home computer with proper programming could identify this type of cognitive error in a few seconds; whereas, it might take weeks for the normal school system to have the opportunity to pick these errors up.

Chart
㉔

Simulation/Games

- Discovery learning
- Multiple variable implications
- Motivation of competition

Chart
㉕

Learner Profile

- Audio retention
- Dyslexia
- Learning decay rate
- Cognitive skill and bugs
- Latent abilities
- Learning strategies

Chart
㉖

The Participants

- Publishers
- Hardware Manufactures
- Schools
- Foundations
- Government

Chart
㉗

The Problems

- Residue of first efforts
- National planning characteristics
- Hardware without software and curriculum
- Early standards
- Possible backlash

Chart
㉘

Inhumane Metaphor

- Books
- Inhumanity of current system
- Role of teacher

Chart
㉙

Priorities

- Curriculum
- Administrative Packages
- Money for Hardware
- Research

Mr. **Brown**. Thank you very much, Dr. Heuston. We will now take a few minutes for questioning of the first two distinguished speakers before we go or with the next panel.

I guess that we have to follow a classroom practice. You are going to have to raise your hands. When I recognize you, please give your name and any other identification so that the recorder can hear you for the record. Any questions? The lady in the back.

Ms. **Loop**. My name is Liza Loop of LO-OP Center, Inc., 3781 Starr King Circle, Palo Alto, Calif.

Mr. **Brown**. Thank you.

Ms. **Loop**. I have a question at this time on statistics, Mr. Chairman. It is about the 42 percent of the 17-year-old blacks Dr. Heuston mentioned who are functionally illiterate. What percentage of those kids are female and what percentage are male?

It occurred to me that in early learning situations, girls often learn to read more easily and faster than boys so that even if they drop out of school before they are 16, you are likely to have more functionally literate girls. What is the impact of this on the work charts that you showed?

Dr. **Heuston**. I am sorry. I can't give you the breakdown. Those are statistics from the National Assessment of Educational Progress. You can get them by writing to that organization in Denver. They will break it down by type and section for you.

Ms. **Loop**. Yes.

Dr. **Heuston**. I think it is true that women learn, particularly in the elementary school years, more rapidly than men. It is sometimes as much as a 1 to 2 year difference by the fourth grade in terms of the levels. Research shows that, by the closing years of college, men are starting to catch up. That's how long it takes. As far as analyzing your question as to what that means for 17-year-olds or 18-year-olds, I think it simply means we will have more women that are functionally literate than men, in general, but not by a lot.

As far as the work problem goes, in regard to the last part of your question, they both are obviously going to need more work to get their basics up to speed. Again I can only see technology providing the requisite additional work.

Ms. **Loop**. Thank you.

Mr. **Brown**. The gentleman over here to the right.

Mr. **Caravella**. Joe Caravella, National Council of Teachers of Mathematics, Reston, Va. Dr. Heuston, on that same chart you had figures detailing the amount of investment in education. Can you tell me for that period if you took into account the inflation rates?

Dr. **Heuston**. Inflation?

Mr. **Caravella**. Yes.

Dr. **Heuston**. Since the statistics came from the National Institute of Education as part of HEW's research effort for the Office of Education, I once asked Arthur Melmed if he knew. He said that he thought those figures did factor in inflation. I will now ask him again if he could comment.

Mr. **Melmed**. My impression is that inflation is an important fraction of that doubling. I am unable at this moment to say what that fraction might be. Those data do need to be reviewed.

Mr. **Caravella**. Thank you.

Mr. **Brown**. Next?

Mr. **Grice**. Howard Grice from Massachusetts State Board of Education. You did not speak about two problems which occurred to us, at least, the problems of teacher training and teacher acceptance which I'd like to hear your thoughts on; also the highly labor intensive nature of the programming process and the retraining of people to do this.

Dr. **Heuston**. Speaking to those two points, the latter one first. Programs are being written that will be used in the schools, primarily, by outside firms with professional programmers. It is very expensive to produce them initially. However, once they are produced, they are very inexpensive to replicate. We are developing, through authoring systems, the ability to write the programs in English without using computer programmers at all. This will save a great deal of time and money. What was the first part of your question, sir?

Mr. **Grice**. The other area is the problem, as you start to introduce these techniques, of teacher training and teacher acceptance.

Dr. **Heuston**. In terms of teacher acceptance, the chart I gave you with the seven sequences that draw on the results of the first 20 years shows and indicates that we must work with what I call teachers' levels of concern. The best way to enter a school is to have computer-management instruction packages. Soon the teachers and students get used to it and are pleased with the help. Then they begin to realize there are students in their particular class that are not learning because the CMI program is showing them that the student cannot answer certain questions in the diagnostic tests on the computer terminal.

As a result, the teachers soon enter a new level of concern and ask if you can produce the drill and practice material for the students as well. The teachers usually will initiate a request for this additional help. The publishers are now producing materials which, in effect, will start the CMI traditions, the computer management structure, and then will lead gradually to higher levels of concern.

In terms of teacher training there will probably be two ways to do this. One is through developing courses for the teachers' colleges. The other is to conduct workshops in the future to bring the teachers up to speed. Governmental help will obviously be needed in both of these areas because the financial commitment will be beyond the resources of any normal institution.

Mr. **Hoffman**. Irwin J. Hoffman, Denver Public Schools. There is a myriad of microcomputers on the market now. How do you envision the solution to the problem of the curriculum you described being put on all of these different computer systems? I can see that as a very difficult problem.

Dr. **Heuston**. The curriculum will be developed. What will really probably happen is this. After a serious time lag the Government will invest in curriculum prototypes to enable publishers to use them and modify them for their individual product lines.

The problem is that we are going to have to live without the materials for a long time because no one was able to convince the leadership that the microprocessors and videodiscs were really coming. In school district after school district, they call and say they are flooded with microprocessors and ask for curriculum help.

Now, how will we get the program material to them? Let's take a case in point. Apple Computer has been franchised by Bell and Howell for educational usage. They are acting as a publisher. They will publish certain materials for the Apple Computer. If you have an Apple Computer, you can buy from Bell and Howell some of those materials. SRA, in Chicago, another large publisher, will support the Apple Computer. Once you've written your basic program it is not impossible to translate them to other computers. It is important that this translation possibility be kept alive so that if a different computer becomes dominant in the market, there will be programs available for them as well.

Ms. BATES. Madeline Bates, Boston University. I think that the comparison of computers to transportation is a very interesting one. I'd like to make an analogy about that. Giving someone access to public transportation is certainly very good—it is better than letting them go on foot. They can then go more places. By giving them a car, they can go not where someone else determines they should go, but where they want to go. I think there is an analogy here as to literacy.

Now, giving the students access to a computer as end users is one thing, but teaching them to use the computers opens up a whole new field and I would like to hear your comments on that.

Dr. HEUSTON. I'm glad that you said that because a school specializes a huge percentage of its resources for teaching languages. We don't always think of it that way, but mathematics is a language. You're teaching students various inflected languages on the assumption that this will give them power for tomorrow's society. It's important that they also learn the foreign languages, as they will help them. The mastery of abstract symbols (languages) will allow students to have a better future. It is important that they learn to calculate and use these symbols. The computer is certainly going to be the machine that dominates much of the future of our society, so the computer languages certainly deserve to be taught alongside the other ones.

Schools will stress having students take courses in computers, or on them, as a language itself. It does give the student access to a new kind of language and thought patterns that should prove to be very useful for them in the future.

Unfortunately, the real power, as shown by your organization, sometimes comes in powerful simulations that the students themselves cannot build. You can equally well have a journey with a simulation as you can in writing a program itself, so both will prosper, I am sure.

Ms. BATES. Thank you.

Mr. BROWN. I have a problem here. I do want to allow ample time for the panel, which will be next on the program. It is quite obvious that everybody with questions will not be able to be recognized.

I have one question. I have no problem in recognizing myself.

If I may, I am now going to ask a question. Then we will go to the next panel. There will be opportunity to interact with these gentlemen later in the day, so keep your questions in mind.

Mr. Melmed, you presented a rather bleak picture, it seems to me, of the slowness with which the schools would adjust to this revolutionary technological change. You mentioned a 10-year span for curriculum development and so forth.

Mr. MELMED. Yes.

Mr. BROWN. Let me ask both of you this. Is there any possibility that the fact that this technology is moving faster in the market place, that it's being taken into the homes and into the workplace, it's being used for training of workers, and so forth, that the schools may be bypassed? Will the significance of the schools be considerably reduced in our society by virtue of learning taking place in the home and the workplace, such as utilizing this technology through the miracles of cable television, stand-alone computers in the home, training programs in the workplace, and so forth? In other words, is there a threat to the role of the schools in the educational process if things don't move faster than you seem to indicate that they're moving?

Mr. **Melmed.** The schools are a very large institution. We handle, in this country, a larger faction of the school age population than perhaps any other country in the world. We ask many things of the schools. We ask them to keep the youngsters in school. We ask them to handle driver education and alcohol education.

Mr. **Brown.** And sex education.

Mr. **Melmed.** Yes, even sex education.

The role of the schools is not a static one, but a changing one. The schools do attempt to respond to the demands that we put on them. Those demands are not always coordinated and not always well planned. There are some things the schools do well, and others they do less well. For example, employers complain that the schools do not prepare their youngsters adequately for the world of work.

As the demands on the schools change and the nation's technological capacity for education outside of school grows, it may well be that the sharp boundary now separating formal instruction in the school from informal education outside of school will blur, with growing emphasis on the use of technology for formal education outside of school.

Mr. **Brown.** Dr. Heuston, do you care to comment on that, keeping in mind the point that you made about the lack of impact of additional resources and the major technology shift? The Congress would be glad to hear of this, because we are about to cut the school budget anyway.

Dr. **Heuston.** The practical implications are that there will be packages distributed for home instruction to improve areas of the home. Parents will be able to get materials to help their children. The publishers are the vehicles in our society that frequently market the schools and bring the materials in. They work with teachers to keep them up to date on some of the approaches. I feel that the publishers will gradually—as fast as they can afford to—produce excellence for the schools.

There is a difference between the home and the school market. It is kind of blurry in terms of what will happen in the home. For example, Walt Disney has never sold well in the schools, even though parents and children love it. They love it at home. There is the case of whether the parents at home will want serious educational materials or if they will buy only warmed-over Walt Disney with drill and practice. Sesame Street does not fit well in the classrooms, but the home market has been outstanding.

One of the early lessons learned was that students preferred straightforward materials in learning situations. All the funny, supportive cultural entertainment like Donald Duck got in the way. We are going to strip down to very efficient programs that the publishers will sell. If Congress wants to do anything with any budgets, I suggest that you consider that we have a delivery mechanism in a position to serve the schools. We have publishers ready to serve the schools but they lack the capital to develop the programs to support the school market properly.

In the late sixties, over 2 percent of the budget of the school system went to books and audiovisual equipment. At last count, it was down somewhere to about 0.07 or 0.08 of 1 percent, or about one-third of the actual amount that the publishers used to count on. With the kind of investment required to produce materials for the schools, I am afraid there will be a considerable lag between that advent of the hardware—which is upon us—and the promulgation of programs from the pubishers. I hope, and this is a personal hope, and I've not thought that deeply about it, that the new Department of Education will have in its budget a fair amount of money for some rapid curriculum development that can go into the publishers' domain so they can accelerate delivery to the schools.

The schools are fairly flexible. They will, as fast as good materials are brought to them, assimilate and accommodate them.

Mr. BROWN. I recognize, as I said, that there are many other people here today that wish to ask questions. But you do have another shot at this later on.

I would like to proceed with our next panel at this time. I will now ask the four panelists to come and sit up here. As each one speaks, they can take the podium.

The members of the panel are as follows: Dr. J. C. R. Licklider, Laboratory for Computer Science, Massachusetts Institute of Technology; Dr. Maxine Rockoff, vice president, planning and research, Corporation for Public Broadcasting; Dr. Vivian Horner, vice president, program development, Warner Cable Corp.; and Dr. James Johnson, director, academic computing, University of Iowa.

Now, Dr. Licklider will serve as the chairman and leadoff speaker of the panel. When he completes his remarks, I will lay on him the additional duty of recognizing the other panel members and handling the questions from the audience after they're finished.

Dr. LICKLIDER. Thank you.

STATEMENT OF DR. J. C. R. LICKLIDER, LABORATORY FOR COMPUTER SCIENCE, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. LICKLIDER. Congressman Brown and distinguished colleagues and distinguished participants in this extravaganza, which I think is what you called it, a beautiful extravaganza. I am very happy and honored to be here.

For my written testimony, I could not resist putting down onto paper much more than I can say here in the short time that is available.

Mr. BROWN. Without objection, your complete statement will be included in the record.

Dr. LICKLIDER. You are very kind.

What I would like to do, Mr. Chairman, is to talk to you and your colleagues and the members of your staff as though I were saying what we all—all of us here—want to say. Then I will try to leave the opportunity for my colleagues and my fellow participants to say, "That is not what we should have said," and to improve the picture.

There are, essentially, five parts to this:

One of them is a little long and will take half my time. It is my glimpse into the early 1990's to see what education is going to be like.

The second is why information technology may have a major impact on education.

The third is why information technology is not actually having a major impact on education.

The fourth is the nature of the potential impact. That is, what the effects will be if things go strongly—the effects including benefits and costs, and also the dangers involved. I said, "if things go strongly." I didn't say, "if they go well." If they go strongly, they might go either well or otherwise.

The fifth part is what needs to be done to gain the benefits and avoid the dangers.

Now, in order to convey my impression of what information technology is intrinsically capable of doing for education, I want at this time to present a brief sketch of a small part of the educational process as it might be observed in the early 1990's. I think that the technological assumptions that underlie this sketch are realistic, even a bit conservative. It is clear that social and institutional changes take place slowly. I don't offer this as my prediction as to what will actually happen. This is a picture of what could be made to happen.

My heroine is a young lady student, Cheryl. She is 15. She attends a public school. It does not have classrooms with a teacher's desk at one end facing rows of student desk-chair modules. It is laid out like a modern landscaped office, but on a somewhat smaller scale. Each student has a work area. The surface of the desk is an interaction medium. It displays images, pictures, diagrams, pages or paragraphs of text, and it is sensitive to what is written on it—pictures, diagrams, hand-printed characters.

Now, this electronic desk contains a small computer, of course. The computer is connected to a schoolwide fiber-optic network that carries packets of digital information among the desks, computers, and data bases and to the several wall display screens and the several production printers that are distributed about the school.

Cheryl is working at the electronic desk, her desk, and she is shaping up in her mind a picture of the subcontinent of India. Cheryl's objective is not just to be able to draw an accurate map of India. It is to understand some of the culture of India in relation to the geography. She has started with a map of India, drawn by the computer system, and is calling up, from a data base of photographs, images of cities, towns, villages, and then streets, buildings, people, and animals. She sees that there are several different modes of dress, and she wants to associate the modes of dress with the various regions of India. Wanting to do that leads her to formulate a little program. She defines a set of 10 regions of India by outlining them on the map. She identifies the regions as R.1 through R.10. She tells the data base to provide pictures of people, individual people, in India, in the 10 regions. She says to call the typical picture "the j-th picture from the i-th region." This bit of mathematical jargon is old stuff to Cheryl. She has known about lists and arrays and indexes since grade school. She says to let the number of pictures available from the i-th region be N_i. Then she says, "Do the following 100 times. Draw a number at random."

That is no doubt enough of that. She is making a little program. I won't give you the details. But we all know, all of us who have seen children work with computers, that they can do it.

Having thus prepared her program, she tells the computer to execute it. The program presents a picture. The student guesses which region the picture comes from. The computer checks to see if that is right. It says, "Good, you are right." Another time it will say, "No, you are wrong." It tells what is wrong if you are wrong. As I said, having prepared the program, Cheryl executes it and responds to each presentation. When she is finished with a set of 100 trials, she has to face the fact that she has identified the region by its index correctly only on 20 of the 100 trials.

She sees that the main trouble is that she can't remember what region the index i corresponds to. That is to say, a large part of her difficulty is with the response and scoring system. She sees that she can improve her program by incorporating into it a little table in which the index numbers are associated with the names of the regions. Then she can respond by giving the names of the regions and will not have to remember the arbitrary index numbers.

In a little while, she has fixed the program so all that she has to do is type the first letters, one or two characters, of the names of the regions. Then everything works smoothly, and she proceeds with further series of pictures.

It never occurs to Cheryl that she is writing a program that would have called for a professional programmer 20 years ago. It certainly shouldn't have. What she is doing here is simple, but it is interesting and effective.

Having developed some skill at telling where the people live from their appearances, Cheryl is pulled in two directions. She wants to demonstrate her newly acquired ability, and she wants to learn more about the people of India. She decides to show off a bit first, then augment her program.

She checks to see whether or not Johnny, Sue, and Bill are on line. Sue and Bill are. They are both accepting notes at the time. She sends Sue and Bill a note. She says, "I have a neat new test for you. It will take just a minute. May I show you some stuff on your displays, or will you come over here?" Bill responds by coming right over. He likes Cheryl. Sue was not born yesterday, and she knows enough to say she'll accept output on her display.

In no time, Cheryl is testing out Bill's and Sue's ability, which of course is almost nil, to associate pictures of the people of India with the parts of India in which they live at the time.

Cheryl displays her newly won mastery and accepts the positive reinforcement provided by Bill and Sue. I think that reinforcement is a very important part of the whole thing. But what Cheryl is thinking about is that her program should really be a competitive game. It would be neat to pit Bill against Sue at the same time, or to let any number of people play. Indeed, they could play at their own desks or play simultaneously and watch their scores go up or down relative to the others. But that calls for control of the system that Cheryl has not learned yet. She is torn between learning about that, which will take some time, and expanding the scope of her learning program. It isn't clear whether it is a learning program or a game—or both. She wants to bring in to the program the names of some of the things in the picture, the names of the styles of clothing, the names of the castes and other groupings of people, and so on. After some vacillation, she decides to take the first step toward learning how to control the presentation of information on other people's displays.

At this point we come to an important part of the school in the 1990's.

Cheryl sends one of her teachers a note via the message system. It is sent to JHB from Cheryl. It has as its subject, "Learning the net." She indicates what she wants to learn. Details are in the written version of my testimony.

JHB is a teacher who knows a lot about the new educational technology. He receives Cheryl's message. He doesn't read it until later in the afternoon. He is a teacher, but he doesn't spend very much time in front of a class. He is mainly dealing with the notes and doing the individual stuff. He writes Cheryl back a rather lengthy note, with carbon copies to Sally W., to Martinez, and so on. It is about how to set up a "plex" on the net. It tells Cheryl that there is a new scheme for setting up plexes that let you deal with separate consoles very easily. There is going to be a special meeting about the new scheme. Can Cheryl come to it Wednesday afternoon?

When a message comes in, a light flashes. Cheryl is reading an article about the French perfume industry in Le Soir when Burton's message arrives, and the flashes in the corner of her eye get her attention.

The way Cheryl was reading Le Soir is interesting. Let me digress on it a minute. The program has both French and English versions of the articles in the paper. The two versions of an article are interconnected by pointers, and the program will substitute the English version of a phrase for the French version whenever Cheryl touches the French version with her stylus.

So, then, Cheryl is reading along, touching this phrase and that, and the program is counting the substitutions and maintaining a record that shows how Cheryl is improving in her mastery of French. The program estimates the difficulty level of the text in terms of Rudolf Flesch's "Flesch Count," and it shows the frequency of instances of substitution as a function of both the difficulty of the text and the time since Cheryl started studying French.

Seeing the flashing light, she pushes down the French program, so that she can return to it and resume without losing her place. She invokes MSG, the program that deals with messages. She says, "I'll be there at 3." She gets an idea as she is doing this. She continues, "Or, if this is a teleconference, I'll be on line. Let me know which it is." It would be neat if the message system could remind you when you forget to say whether the meeting is a face-to-face meeting or a teleconference.

Now, Cheryl is thinking thoughts a little like a programmer. She is 15. That might sound as though I am being unrealistic, but it should not. That is the way it is.

Now, Cheryl has other work to do. I am not, at this time, going to go through all of it. But she wants to get into this India thing. She turns to the information retrieval system. It requires that she follow precisely a rather demanding procedure in order to specify the topic of interest. Cheryl types a set of descriptors. I'll spare you the details here. She thinks that this is a terrible drag, that the notation is a mess. But she wants to get the best stuff in the data base. Her descriptors get her a list of 10 likely sources in the data base, which she can proceed to examine on her display. Before she begins to do that, however, it occurs to her to see whether there is anything of pertinence, yet, in the new knowledge base that is being worked on by the artificial intelligence people. The knowledge base does not require such fussy syntax. Cheryl types:

> **KB. What do you have about the costumes and appearance of people in the various parts of India?**
>
> **And KB replies: I know many things about the people of India, the styles of clothing that are worn in the various parts of the country and by the members of the various castes, and the appearances of the various ethnic groups that comprise the population of India.**
>
> **Do you want to ask me specific questions, or would you like a brief summary of what I know about this topic?**

That scenario took a long time. What I wanted it to do was to suggest these things:

That education can be built into an interesting, social, active way of life. The individual student can take a lot of initiative and choose directions that are interesting to him or her.

That educational technology can provide a stimulating environment for learning, and that such an environment is to be preferred over machines that cram information into people. I am against the cramming.

That educational technology can introduce both efficiency and effectiveness into the lives of teachers, by giving them the time and facilities that they need to work effectively with individual students. The technology should do the part of teaching it can do best and free the time and energies of the teachers for inspiration and reinforcement.

That a lot can be done with the techniques and methods that are already understood.

That there is time between now and the 1990's to develop some sophisticated knowledge-based systems, but even then there will still be continuing work on such systems. The sophisticated systems will not have displaced the standard stuff.

That the educational computer-communication systems of the 1990's will deal with images quite as well as with numbers and symbols. They will work with speech, too, but perhaps a bit less well.

That students in good learning environments will feel some stress from having so many interesting avenues to explore and from sometimes having to make painful choices among attractive alternatives.

That students can be creative and valuable sources of educational software. I believe that very strongly. In my budget estimate, half the software money goes to professional programming shops. The other half goes to extracting software from the process of education. It goes mainly to teachers and students. I know that, at the college level, students can create useful programs. I am pretty sure that will filter down into the high school. Perhaps it will go even further.

The use of computers will blend into the programming of computers, and students will do a lot of their learning by programming, by preparing and testing programs that help them interact with the information and knowledge that is available to them.

The computer-communications system of a school will be a distributed system, a network. It will be part of a network of networks that will reach across the United States and perhaps into other countries. I did not go so far as to put Cheryl into direct communication with students in schools in India, but I was not inhibited from doing that by any essential technological barrier.

Now, the rest of what I have, Mr. Chairman, has a lot of points in it. I am just going to touch upon them. I have come to realize, in being here this morning, that a lot of us know the same things and believe the same things. I think that the key to all of this is to figure out how we can start moving—how to stop saying to ourselves that we, ourselves, have the insight and the enthusiasm, but that we live in a country that has turned the damper down. We sense the potential for a significant advance in education, but don't know how to get started.

Next, Mr. Chairman, is why information technology may have a major impact on education.

First, education needs help. That is a paragraph you can read and apply.

Second, information technology is advancing very rapidly. I echo the comments of my colleagues. Let me read just one paragraph about this.

> The personal or hobby computers that you can buy at the computer store today for $750 are more powerful and faster and hold more information than the first core-memory machine I had the pleasure of working on. It was the very first production PDP-1 computer, the first production computer made by the Digital Equipment Corporation, and it cost about $150,000 in 1958. That is a cost-reduction factor of more than 200 in 22 years. The factor of speed increase is about 10, from 10 microseconds per instruction execution to about 1 microsecond. The factor of increase in processing power per instruction is smaller, and we may neglect it for the purpose of showing that the double-every-two-years rule checks out. Just note that the factor of 200 and the factor of 10 combine to yield 2000, which is almost exactly the result of 11 doublings, one every 2 years for 22 years. Eleven doublings yield a factor of 2048.

Doubling every 2 years is an easy rule-of-thumb for the overall advance of computer hardware. It is comparable to the rule for semiconductor chips, which my slightly enthusiastic colleague said was doubled every year. I'd say, for the chips, double every 14 months. The fact that, when you take computer hardware as a whole, it is only doubled every 2 years reflects the fact that the power supply does not advance as rapidly as does the chip.

The advance of computer hardware technology is by no means limited to semiconductor chips, however. Great things are happening, for example, in electronic beam service, laser printers, and magnetic bubble devices that have even higher bit densities than the semiconductor devices to which we have been referring.

Let me say a word about video disks. There are really two waves here. There is the analog video disk that's coming out in the commercial entertainment market. It offers a tremendous opportunity for educational application. But coming on its heels, in 3 years, perhaps, is the digital video disk. It will hold about 10 billion bits of information. You ought to figure how much information that is. On one plastic disk the size of a phonograph record you will have the equivalent of 1,000 books. The cost of a video disk, in quantity reproduction is just a few dollars.

One more thing about the video disk is this. Then I will be through with this outpouring of enthusiasm for technology. A friend of mine at MIT, Nicholas Negroponte, runs a beautiful laboratory in the School of Architecture in which he and his associates work on computers in support of architecture. They went to Aspen, Colo. They photographed the roads and streets at 10-foot intervals. Then they transferred the pictures onto a video disk controlled by a computer. You sit in the driver's seat of an automobile, turn the steering wheel, and drive around Aspen. As the vehicle moves down the street and around the corner, the computer selects and presents the view that you should see. The trip is a bit jerky because the photographs were taken only every 10 feet, but the effect is real and compelling. With 50,000 pictures on a video disk and video disks at $10 each, one could store 50 miles worth of pictures taken just 1 foot apart for the cost of an airplane ride from New York to Aspen and back. So much for travel in the future. If we ever got into a bad energy shortage, computer controlled video disks will help.

In my written testimony, there is a section about software. The sense of it is that software is not as magic as hardware but that we are over the hump on several software problems. The good programming group can now make big programs on schedule. This doesn't solve all of our problems, but it introduces further optimism into the overall prospect for educational applications.

In my budget estimate, the software cost came out to be only half the hardware cost. The reason for this is that, once you get the software, you can replicate it at essentially no cost. Education will have a much bigger replication factor than most other applications.

Now, to look at the benefits with a hard eye. You are living in the United States. It is full of hard-eyed people. The name of the game is "productivity." We are slipping. We are declining. It is clear that our on-the-whole terrible performance in education is, in large part, responsible for the decline. You try to find out why Japan is doing so relatively well. You see that, at this time, Japan has superior education at almost all levels. This is true, also, in other countries such as West Germany.

I think that the key to reversing the decline is part education and part information technology. Good use of information technology in business and industry would help us greatly. There isn't any other way to get productivity turned up in a short time. But this is about information technology and education. To make a major difference in education will take a decade. I think we may just have to learn to live with one-and-one-half-class citizenship in the world community for a few years. And during that few years we had better "get ourselves together."

Next, consider quality of life. Maybe we are running out of gasoline. Maybe we can't travel all over when we want to. But learning to explore the world of knowledge, to explore information bases, and knowledge bases, can be quite as interesting, quite as exciting. All of us who have had experience with well-programmed works such as the ARPANET know that it can be compelling. It is hard to go away from the computer console. It makes us sad to realize that in the rest of the world out there there are so many kids who are turned off and unhappy. Many of them are on drugs. They don't know that online interaction with a good computer is a better addiction. It is just as exciting, and it builds instead of destroying. The quality of life can be turned around.

Let us now go to the danger side. I believe that it is easier to exploit technology than it is to apply it wisely. I believe that, if educational applications are driven only by the forces of the marketplace, would-be exploiters are going to get in there with a lot of inferior stuff before the good stuff is developed. It is likely that we will have an emphasis on factual information that is easy to "input" into the computer and easy to "drill" into the student. It is possible that a bad government or other ideological organization will exploit the image of the computer as all-knowing and infallible. If the schools were "computerized" and "netted" and the Government wanted to control the students, technology would present an awfully efficient way to do it. There is danger there. There is danger that the technology will turn out to be so effective that it gets into the schools over the dead bodies of the teachers and, in the process, creates a disruptive adversary situation in the schools. Your imagination is as good as mine in picturing the dangers. I just want to be sure that that aspect of the matter is examined, discussed, and overseen.

Thinking about the dangers should not be left entirely to antitechnologists. Technologists should list the dangers and study them. Oversight will be critically important. Year by year, or 6 months by 6 months, there should be checks on the situation. We can't allow technology to shape education to the profit or convenience of technologists or to the will of political ideologists. Equally, we can't allow ourselves not to use technology just because powerful forces are dangerous.

There's a lot more that I'd like to say, but, because of the time, I'll just refer you to the written testimony.

Thank you very much. [Applause.]

[The complete statement of Dr. J. C. R. Licklider follows:]

SOCIAL AND ECONOMIC IMPACTS
OF INFORMATION TECHNOLOGY
ON EDUCATION

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1. A GLIMPSE OF EDUCATION IN THE 1990s

In order to convey an impression of what information technology is intrinsically capable of doing for education, I want to begin with a brief sketch of a small part of the educational process as it might be observed in the 1990s. I think that the technological assumptions that underlie this sketch are realistic, even a bit conservative. On the other hand, it is clear that social and institutional changes usually take place slowly, and I do not offer the following impression as my prediction of what will actually happen. I offer it as a picture of what could be made to happen.

Cheryl is 15. She attends a public school. It does not have classrooms with a teacher's desk at one end facing rows of student desk-chair modules. It is laid out like a modern 'landscaped' office, but on a somewhat smaller scale. Each student has a work area. The focus of the work area is an 'electronic desk'. The surface of the desk is an 'interaction medium'. It displays images -- pictures, diagrams, pages or paragraphs of text -- and it is sensitive to what is written on it -- pictures, diagrams, hand-printed characters. It is sensitive, also, to what is pointed to (touched) in the images it displays. The electronic desk contains a small computer, of course. The computer is connected to a school-wide fibre-optic network that carries packets of digital information among the desks, computers, and data bases and to the several wall display screens and the several production printers that are distributed about the school. It is connected, also, to external networks that link Cheryl's school with other schools and, indeed, with all the organizations and individuals reachable through the general packet networks.

Cheryl is working at her electronic desk, shaping up in her mind a picture of the subcontinent of India. Cheryl's objective is not just to be able to draw an accurate map of India. It is to understand some of the culture of India in relation to the geography. She has started with a map of India, drawn by the computer system, and she is calling up, from a data base of photographs, images of cities, towns, villages, and then streets, buildings, people, animals. She sees that there are several different modes of dress, and she wants to associate them with regions of the country.

Wanting to do that leads her to formulate a little program: She defines a set of ten regions of India by outlining them on the map. She identifies the regions as R.1 through R.10. She tells the data base to provide pictures of people, individual people, in India, in the 10 regions defined. She says to call the typical picture, the j-th picture from the i-th region, picture P.i.j. (This bit of mathematical jargon is old stuff to Cheryl. She has known about lists and arrays and indices since grade school.) She says to let the number of pictures available from the i-th region be N.i. Then she says: 'Do the following 100 times -- Draw a number at random from 1 through 10, and let it be the value of i. Then draw a number at random from 1 through N.i and let it be the value of j. Present picture P.i.j. Accept a response (pressing of a key, 0 to 9, with 0 representing 10) from the keyboard. If the response (with 10 substituted for 0) equals i, the index of the region, display 'Right!'. Otherwise, display 'Wrong!' and then display the actual value of i, the index of the region.'

Having thus prepared her program, Cheryl tells her computer to execute it. She responds to each picture it presents. When she has finished the set of 100 trials, she has identified the region (by its index) correctly only on about 20 of the 100 trials.

In part, her low score was due to the fact that she had trouble remembering which index number identified which region. She sees that she can improve her program by making it refer to a small table in which the index numbers (1 to 10) are associated with the names of the regions. In a little while she has fixed the program so all she has to do is type the first letter or two of the name of the region, just enough to identify it uniquely. Meanwhile, in the process of debugging her program, she has learned to associate most of the costumes -- or facial types or physiques; she is realizing that what she is learning is a mix of characteristics -- with the regions in which they prevail. She now has her program keeping score, counting how many times she is correct out of a hundred. Next she will make it keep track of past scores and plot graphs showing her progress with the learning task. It never occurs to her that she is writing programs that would have called for a professional programmer twenty years earlier. It is all simple and natural, and very rewarding because she can command the resources at her disposal with progressively increasing facility.

Having developed some skill at telling where the people live from their appearances, Cheryl is pulled in two directions: She wants to demonstrate her newly acquired ability, and she wants to learn more about the people of India. She decides to show off a bit first, then augment her program. She checks to see whether or not Johnny, Sue, and Bill are on-line. Sue and Bill are, and they are both accepting notes. She sends Sue and Bill a note: 'I have a neat new test for you. It will take just a minute. May I show you some stuff on your displays, or will you come over here?'

Bill, who was exploring the inverse-square law of gravity by playing with a simulation of space flight in which the distance coefficient in the law of gravity is a variable parameter, responds by going right over because he likes Cheryl. Sue was not born yesterday, and she knows enough to say she'll accept output on her display. She is a little reluctant to interrupt her experiment, which is on a topic of intense current interest, but she frees up her *display and links to Cheryl's.*[1] *In no time, Cheryl is testing out Bill's and Sue's ability -- which, of course, is almost nil -- to associate pictures of the people of India with the parts of India in which they live. Cheryl displays her newly won mastery and accepts the positive reinforcement provided by Bill and Sue -- but what Cheryl is thinking about now is that her program should really be a competitive game. It would be neat to be able to pit Bill against Sue -- or to let any number of people play. Indeed, they should play at their own desks, so they can all play at once and watch their scores go up or down relative to the others'. But that calls for control of the system that she hasn't learned yet. She is torn between learning about that, which will take some time, and expanding the scope of her learning program -- It isn't clear whether it is a learning program or a game; actually, it is both. -- to bring in the names of the items and styles of clothing, the names of the castes and other groupings of people, and so on. After some vacillation, she decides to take the first step toward learning how to control the presentation of information on other people's displays.*

So Cheryl sends one of her teachers a note via the message system:

```
To:           JHB
From:         Cher
Subject:      Learning the net

        How do I go about learning how to put pictures and text
on other students' displays?  I know I will have to have their
permission.  I know how to put the pictures and text on my own
display.  And I can put exactly the same stuff on one or more
other displays by linking to the other consoles.  But I want to
send different pictures to different displays at the same time.
I need to know about this in order to build a test game in which
I can present pictures to several people at the same time --
different pictures to different people -- and have them respond
by trying to identify or classify the pictures.  It is a neat
game test, but it just works for one person now.  Please help
me.

                                  Yours

                                  Cheryl
```

---

[1] Many of the students are involved in an informal and somewhat competitive experiment to see whether a person can learn to see a 4-dimensional object as, in direct visual perception, a truly 4-dimensional object. The computer has no trouble, of course, representing objects of more than three dimensions. And it can display, on its 2-dimensional display screen, dynamic, perspective, 3-dimensional sections of 4-dimensional objects in its memory. Sue has been spending an hour a day for the last several weeks, systematically interacting with such sections of 4-dimensional objects, and she thinks that something is happening in her visual perception. Many other students are conducting related experiments, and there has been much discussion of what it would really mean to 'see in four dimensions'. A special interest group has formed on this subject, and everyone is looking forward to a meeting, later in the week, in which an experimental psychologist who has done research on the subject is going to discuss the psychology of visual perception.

```
↑Z

• Send

[Sent to JHB.  Carbon sent to Cher.  End.]
```

JHB is Jim Burton, a teacher who knows a lot about the new educational technology. He receives Cheryl's message right away but doesn't get around to reading it 'til later in the afternoon. He is happy to see that Cheryl is wanting to branch out, to learn to use more sophisticated features of the system. He sends her a reply message:

```
To:             Cher
Cc:             Sally W., Martinez, Martin Vilas at Pershing
From:           JHB
Subject:        How to set up a plex on the net
        What you are doing sounds great!  And it may be easy to
do.  There is a facility on the net called the 'plex' facility.
It lets you connect any number of consoles, which you must
identify, into a system that your program can deal with as
'console 1', 'console 2', 'console 3', and so on.  Or, if you
like, you can give them names in your program and then refer to
them by name.

        To get started on plexes, read 'PLEXES' under 'NETWORKS'
in the 'DOCUMENTATION' directory.  Then we can have a tutorial
on plexes.  I am trying to set one up for Wednesday afternoon
with Harry Bostich, who did some of the programming on the plex
system.  Are you free at 3:00?  Sally Wurtz, Bill Martinez, and
Martin Vilas (Vilas from Pershing High) are interested in
plexes, too, and want to participate.

        Do you know that there is a SIG on drill-and-practice
systems (You can put your name on the list in the SIG directory
under 'SIG-DAP' to get messages on DAP programs.) and a SIG on
video disk data bases (SIG-VID-DB in the SIG directory)?

        Please put me on your documentation distribution list if
you write up your program.  I hope you will.

                                Regards

                                Jim

↑Z

• Cc:  James Bostich at Educational Testing Service (Princeton)

• Send

[Sent to Cher.  Carbons sent to JHB, Sally W., Martinez. Carbon
queued at Pershing for Martin Vilas.  Carbon queued here for
James Bostich.  End.]
```

Whenever a message arrives at Cheryl's desk, a little light flashes. Cheryl is reading an article about the French perfume industry in Le Soir when Burton's message arrives and the flashes in the corner of her eye get her attention. The article is from a special database that contains both French and English versions of everything in Le Soir. The French and English versions are interconnected by pointers, and the program through which Cheryl is reading will substitute the English version of a phrase for the French version whenever Cheryl touches the French version with her stylus. The program counts the substitutions and maintains a record that shows how Cheryl is improving in her mastery of French. Of course, the program estimates the difficulty level of the text (in terms of Rudolf Flesch's 'Flesch Count') and shows the frequency of instances of substitution help as a function of both the difficulty of the text and the time since Cheryl started studying French.

Seeing the flashing light, Cheryl 'pushes down' the French program (so she can return to it and resume without losing her place) and invokes MSG, the program that deals with messages. She reads Burton's reply and replies to it. All she has to tell MSG, of course, is what to put into the body of the response: MSG knows to whom to send it. She says, 'Thanks, I'll be there at 3:00 -- unless I hear from you that the tutorial is a teleconference, in which case I'll be on line.'. Cheryl thinks to herself: 'It would be neat to have the system remind you when you forget to say whether the meeting is face-to-face or on-line. All MSG would have to do is to scan the message for words and phrases that would indicate one way or the other, and, if it didn't find any, give you a suggestion at the point where it says 'Sent'. Maybe I should get acquainted with the SIG on message systems and see whether anybody is working on that.'

But Cheryl has other work to do now. She starts out to explore SIG-DAP, first calling up its charter on her display and then its membership list. The latter is long, covering the whole school district, and not broken down by schools. So Cheryl gets the subset of the membership list that is the set intersection between the membership list and her own list of acquaintances. Indeed, this whole business of sets and set unions and set intersections just came up in her mathematics class last month, and she has already found a lot of uses for it. Right now, she sees that three of her acquaintances are members of SIG-DAP, so Cheryl checks to see whether any of the three are on-line and accepting. Jerry Serona is. Cheryl asks him via the BUT-IN system whether he has time to link, and soon he is telling her what happened at the last SIG-DAP teleconference. When they are finished with the link, Cheryl browses through the record of the teleconference and finds that there is a lot of activity that is related in method, though not in subject matter, to what she is doing. That fact sets off in her mind the idea that there may be activity relating to India, costumes, styles, regions, ethnic groups, and so on that is not associated with drill and practice. Indeed, there may be some good TV segments on India and its people. So she makes *some notes about all the ideas that are beginning to form -- so she won't forget them -- and then gets into the data base with the set of descriptors:*

```
<top-10 <& India
           <| costume style>
           <| region ethnic tribe>
           <| caste class>
           <| image photo photograph picture>>>
```

That bit of information retrieval, which most of the students consider tedious but necessary, gets her a list of ten likely sources in the data base, which she can proceed to examine on her display. Before she begins to do that, however, it occurs her to see whether there is anything of pertinence, yet, in the new knowledge base that is being worked on by the artificial intelligence people. The knowledge base does not require such fussy syntax. Cheryl types:

```
<KB: What do you have about the costumes and appearance
of people in the various parts of India?>
```

And KB replies:

```
I know many things about the people of India, the styles of
clothing that are worn in the various parts of the country and
by the members of the various castes, and the appearances of the
various ethnic groups that comprise the population of India.

Do you want to ask me specific questions, or would you like a
brief summary of what I know about this topic?
```

Cheryl points to the latter alternative with her stylus, and KB begins to display a summary that it constructs, on an ad hoc basis, from its internal KRL base, translating the pointer structures into English at a level suitable for communication with a person with Cheryl's profile of cognitive skills, preferences for display media and formats, and substantive knowledge.

Although the foregoing scenario was severely limited in scope and variety, touching upon only a few of the many new techniques that are perti[illegible] education and upon only a couple of the thousands of subjects that students need to learn about -- and dealing with only one level of student age and capability -- it will have to suffice as an introduction. Some of the things I wanted it to suggest are:

1. That education can be built into an interesting, social, active way of life.

2. That the individual student can take a lot of initiative and choose directions that are interesting to him or her.

3. That educational technology can provide a stimulating environment for learning, and that such an environment is to be preferred over machines that cram information into people.

4. That educational technology can introduce both efficiency and effectiveness into the lives of teachers, by giving them the time and facilities they need to work effectively with individual students. The technology should do the part of teaching it can do best and free the time and energies of the teachers for inspiration and reinforcement.

5. That communication with other students is an important part of the educational process.

6. That a lot can be done with techniques and methods that are already understood and proven in applications other than education.

7. That there is time between now and the 1990s to develop some sophisticated knowledge-based systems, but that work on such systems will still be continuing in the 1990s.

8. That the educational computer-communication systems of the 1990s will deal with images quite as well as with numbers and symbols. (They will work with speech, too, but perhaps a bit less well.)

9. That students in good learning environments will feel some stress from having so many interesting avenues to explore and from sometimes having to make painful choices among attractive alternatives.

10. That students can be creative and valuable sources of educational software. (Their software will have the advantage of evolving through competition with the software prepared by other students. When student-produced (and teacher-produced) software has proven itself in such competition, then professional programmers will go over it to make sure that it is bug-free and user-proof, but a lot of the real invention will come from students and teachers -- not all of them, but quite a lot of them.)

11. That the use of computers will blend into the programming of computers, and that students will do a lot of their learning by programming, by preparing and testing programs that help them interact with the information and knowledge that is available to them.

12. That the computer-communication system of a school will be a distributed system, a network -- and that it will be part of a network of networks that will reach across the United States and perhaps into other countries. I did not go so far as to put Cheryl into direct communication with students in schools in India, but I was not inhibited from doing that by any essential technological barrier.

2. WHY INFORMATION TECHNOLOGY MAY HAVE A MAJOR IMPACT ON EDUCATION

2.1 Education Needs Help

In the United States, education is far less good than it could and should be. In the assessment of people whose judgment I trust, education in not as good in the United States, on the average, as it is in a few other countries, including West Germany and Japan. Education is highly labor intensive, not as well supported by technology as are, for example, manufacturing, transportation, farming, and medicine. Education is beset by economic and motivational problems and by competition from commercial television and drugs. Education is not perceived as part of real life by most students, and real life takes precedence. National achievement test scores indicate that school education is on the decline. In short, education needs help, and a natural place to look for help, since education deals mainly with information, is information technology.

2.2 Information Technology is Advancing Very Rapidly

The capability and cost-effectiveness of information technology have been advancing exponentially since World War II. 'Advancing exponentially' is a trite phrase, but in this case it is also a correct phrase, and, moreover, the exponent is very high. The key fact is that, ever since 1943, the amount of information processing that can be done per unit time by one dollar's worth of computer hardware has been doubling approximately every two years. No other technology has established such a record. Only the advances in explosive power (fission bomb and fusion bomb) and vehicle speed (rockets) even came close. Indeed, in the presently most critical area of information hardware technology, called 'large scale integration of semiconductor devices', the cost-effectiveness of semiconductor 'chips' has doubled about every 15 months since 1965, and only this last year has inflation been high enough to cause people to say: 'Is that in current or in fixed-year dollars?'.

2.3 Examples of Technological Advance -- Hardware

1. The personal or hobby computers that you can buy at the computer store today for $750 are more powerful and faster and hold more information than the first core-memory machine I had the pleasure of working on. It was the very first production PDP-1 computer, the first production computer made by the Digital Equipment Corporation, and it cost about $150,000 in 1958. That is a cost-reduction factor of more than 200 in 22 years. The factor of speed increase is about 10,

from 10 microseconds per instruction execution to about 1 microsecond. The factor of increase in processing power per instruction is smaller, and we may neglect it for the purpose of showing that the double-every-two-years rule checks out. Just note that the factor of 200 and the factor of 10 combine to yield 2000, which is almost exactly the result of 11 doublings, one every 2 years for 22 years. Eleven doublings yield a factor of 2048.

2. An electron beam device, writing a pattern of 'bits' on a small wafer of semiconductor material, can store about 100 billion bits, which is the digital equivalent of about 3 million pages of typewritten text -- roughly 10,000 books of text.

3. Laser printers, controlled by computers, can print serveral pages of high-quality text and graphics per second. The type fonts and graphic figures are under program control and therefore limited only by the imagination and skill of people.

4. Magnetic bubble devices have even higher 'bit densities' than the wholly electronic semiconductor devices.

5. Communication satellites are opening up channels for computer-to-computer communication that will transmit 50 million bits per second. The channels of the ARPANET, heretofore the nationwide computer network with the highest information transmission rate, transmit 50 thousand bits per second. There is an increase by a factor of 1000 in capability, and it is accompanied by a very large decrease in cost per bit.

6. The television commercials do no exaggerate when they say that optic fibres the diameter of a human hair will carry more than 100 million bits per second. That amounts to more than 10 books of text per second per fibre.

7. The 'Josephson junction' is a microscopic device that seems likely to open up a technology that may be the successor to the semiconductor chips that now account for so much of the magic of computer technology. Josephson junctions are extremely small, extremely fast, and require extremely little power. The work about a hundred times as rapidly as chips do. The only trouble is that they have to be kept very cold, very close to absolute zero.

8. The video disks that are appearing on the market at $10 or $20 each hold about 50,000 frames (images) of television (video) information. They are not digital devices, but digital versions of them are being developed. One digital video disk will hold about 10 billion bits. That is the equivalent of a thousand books of text. There is no technological reason that such disks cannot be duplicated for a few dollars each. The least expensive digital video disk playback now costs between $2000 and $3000, but mass production would bring the cost down toward the cost of an analog video disk playback, about $800. One cannot contemplate those figures without sensing a tremendous potential impact -- a tremendous impact on education and on the publication industry and commercial television as well.

9. Since video disks and other high-storage-capacity devices can store images as well as text, it is possible to put a library of tens or hundreds of thousands of pictures on an individual's desk. Nicholas Negroponte, director of 'The Architecture Machine' group at M.I.T., recently demonstrated a computer-based tour of Aspen, Colorado. The viewer sits in the driver's seat of a

simulated automobile and drives around Aspen. As the vehicle moves down the streets and around the corners, the computer makes the view change as it should. The trip is a bit jerky because the photographs were taken only every ten feet, but with 50,000 pictures on a disk and disks at $10 each, one could duplicate on video disks 50 miles worth of pictures taken one foot apart for the cost of a trip from New York to Aspen and back.

2.4 Areas of Technological Advance -- Software

Although the art of programming and the art of managing data have lagged behind the art of building hardware computers and communication systems, and although 'software' has been blamed for spoiling the magic of information hardware technology, there have been very significant advances in the software side of information technology.

1. The best modern languages for writing programs and for controlling computers are very much better, very much less focused on the tedious details of moving bits around in the memory of the machine, than are the old languages. The trouble is, most people still use the old languages.

2. Programming is much easier when it is done in direct interaction with the computer. The best programming groups now use 'interactive programming' almost exclusively. The trouble is, many programming groups are still doing it the old way.

3. The best programming groups now have sophisticated programming systems, with large libraries of well tested and well documented program modules and systematically organized test data. Having a good programming system is as important as programming in a good language.

4. The concept of 'structure' in computer programs has been developed significantly. A 'structured program', written in a highly structured programming language, is much simpler and easier to write, explain, understand, and update than is a functionally equivalent 'unstructured program'.

5. The best software groups are now doing their work pretty much on schedule, at estimated cost, with remarkably few bugs, and they are documenting their software clearly. That is quite different from the way it was (even in the best of software circles) ten or fifteen years ago.

2.5 Microcomputers, Personal Computers, Hobby Computers, Home Computers

The TRS-80s, Apples, PETs, Sorcerers, Ataris, OSIs, ... that can be bought for less than $1000 at the local computer store are changing almost everyone's concept of 'the computer'. Perhaps the change began with pocket calculators, and surely it will continue with microprocessors 'embedded' in automobiles, heating systems, air conditioners, toasters, ovens, and television sets. It is difficult to estimate how many computer-store computers have been sold in the United States because it is difficult to define such a computer, difficult to cut between 'real' computers and 'mere' calculators and 'mere' games. But the number of legitimate home, hobby, home, personal, and small-business computers is somewhere between 300,000 and 1,000,000, and it is increasing very rapidly. Moreover, the capability of the computers is increasing very rapidly, too. All this has raised the question, 'Are these small machines the answer to the needs of education?'

The answer is not an unqualified 'yes', but there is enough 'yes' in it to make the present day microcomputer a very strong forcing function, to make it one of the reasons for believing that information technology truly is going to do something big for education.

First, why the 'yes' is not unqualified: The inexpensive machines available today are comparable in capacity and power to much more expensive machines used in research on computer assisted instruction during the 1960s, and the capabilities and limitations of such machines for educational applications are fairly well understood. They are capable of handling drill and practice applications and of providing a tutorial mode of instruction in applications in which the only a small amount of information is dealt with at any one time. They are capable of executing interesting and dramatic games, indeed, of producing rapid-fire action, provided that the games do not involve large amounts of information. They are not capable of handling data bases of even modest size. They are not capable of storing, for example, the equivalent of a single school book. (Raising the price level to $2000 or $3000 brings book-sized information bases into the picture.) Thus the present-day low-cost microcomputer is on the verge. It can do enough to make it very interesting, to excite students (and others, also), and to present -- to anyone who can extrapolate -- a pretty clear picture of what the future is going to be. But, when assessed as revolutionary vehicles in their own right, rather than as harbingers, they give rise to about as many 'yes, but' opinions as 'This is it.'s.

Now, having made the necessary temporizing statement, I can return to a higher state of enthusiasm: The video disk, mentioned as one of the examples of the advances of hardware technology, will soon remove the main limitation of the present day microcomputer. Unfortunately, the video disk subsystem will be at least as expensive as the microcomputer, but the video disk will put tens of thousands of images and hundreds of digital book-equivalents onto or into the desk beside the microcomputer. This technological advance will come in two waves, the first two or three years before the second. In the first wave, most of the information on the video disk will be analog information, pictures of things and pictures of pages of text. The measure of size that is pertinent is 50,000 equivalent television frames. They will be accessible as moving picture segments, as individual images, or as 'slide shows' made of individual frames selected by the computer in any sequence. That wave will be exciting, but it will also be frustrating. The microcomputer, being a digital device, will not be able to do anything with the pictures but find them, count them, and display them. It will use the small amount of supplementary digital information on a disk to select the pictures in interesting sequences, even in sequences that depend on students' responses to them, but the microprocessor will be blind to the content of the pictures. In the second wave, most or all of the content of the video disk will be digital, and that will open up the game.

What can be done with microcomputers plus digital video disks will be very exciting. It will be possible to make learning environments with domains equivalent to hundreds of books. Games and simulations will no longer be restricted to the small data bases that will fit into 'main memory' (say, 10 pages of text) or onto a 'floppy disk' (say, 50 pages of text). Whereas now almost every creator of an educational program sees the limitation of storage space in the microcomputer as the main restriction on what he can accomplish, the video disk will make almost every one admit that the limitation is now his own ability, either his ability to imagine or his ability to convert his visions into software.

Even with the coming of digital video disks, two fundamental limitations will remain. First, although the video disk will hold a very large amount of information at a very small cost, and although the device that reads it will be able to read very rapidly once it finds the proper place, the mechanism that positions the reading element will be slow, and so it will take a long time to search through a large number of alternatives. And that is something that is involved in many computer applications. Second, video disks have to be distributed in advance of use, and that makes them inappropriate for applications in which data are shared and continually changing. It is difficult to tell how restrictive these limitations will be. Fortunately, other areas of information technology offer ways to overcome the limitations, but they raise the question of affordability. Probably magnetic bubble memories will solve the problem of providing inexpensive memory with faster 'random access' than video disks, and telecommunications will provide connections to shared and frequently updated data bases. The affordability of telecommunications will not depend as strongly on the capability of the technology as it will on business considerations such as ammortization policy. It may be desirable for Congress to make a law analogous to the one that makes it inexpensive to send books through the mail, a law that would make it possible for schools to afford to net themselves together and for everyone to gain electronic access to data bases and knowledge bases of educational significance.

2.6 Confluence of Computers and Communications

The fact that major segments of computer technology and communications technology have in effect merged greatly increases the intrinsic capability of information technology to support educational applications. Distributed computer systems and computer-communication networks make it possible, and should -- Here, still thinking about the end of the preceding paragraph, I say 'should' instead of 'will' -- make it economically feasible for people in any part of the country to communicate with one another and with large, shared data bases (and, in due course, knowledge bases) and to use specialized facilities, even though remote. Thus computers owe much of their capability to advances in telecommunications. In turn, telecommunications owes many of its advances to computers, which serve as communication switches, directing the traffic of packets of information on a time scale of thousandths of a second instead of the time scale of minutes that we are used to in our ordinary use of the telephone.

2.7 Information Technology Makes it Possible to Improve Resources Progressively, to Assemble the Best from All Sources, and Then to Distribute it to All Users

This is one of the main keys. Non-technology-based education can be little better than the local resources. Only one or a few localities can have the best of any kind of resource, and none can have the best of all kinds. Information technology offers ways of providing everyone the best. Moreover, it offers ways of improving the best and making it continually better.

2.8 Applications of Computers to Education that Have Been Mastered Work Quite Well

To continue with reasons for thinking that information technology will contribute significantly to improvement of education, we should note that computer-base drill-and-practice systems and programmed instruction systems that deal with definite and concrete information have proven themselves to be effective and cost-effective. In areas in which alternative techniques of training are very expensive, as in the training of commercial aircraft pilots, even highly sophisticated and costly computer-based simulation systems have proven themselves. In many universities it has been found that the best way to teach computer programming is to provide access to interactive computers with good programming systems. And in a few laboratories, it has been shown that computer-based learning environments really do stimulate interest, initiative, and creativity.

2.9 Other Applications, Not Yet Fully Mastered, Appear Very Promising

The final basis for optimism that I want to mention is the preview of the future that is provided by experience in research laboratories. Progress is being made in understanding how to organize information so the computer can use it in the way people use knowledge. That is why I have mentioned 'knowledge bases' as alternatives to, or as successors to, 'data bases'. It is getting to be time to take seriously the notion that computers can process knowledge, and not merely data. Progress is being made in computer processing of natural languages, such as English. Indeed, considerable progress has been made in getting the computer to understand spoken language, and computer recognition of individual words and computer utterance of connected phrases and sentences are now 'state of the art'. There is good progress even in such truly difficult areas as theorem proving, problem solving, decision making, and robotics. The distant future of educational technology is being shaped even now by work in these areas. But there is too much work still to be done for me to say that they are going to dominate educational applications of computers in the next few years.

3. WHY INFORMATION TECHNOLOGY IS NOT ACTUALLY HAVING A MAJOR IMPACT ON EDUCATION

3.1 Much More Work on Educational Applications Needed

Information technology provides the essential raw materials for revolutionary advances in education, but they are raw materials. The have to be processed into educational technology. At the present time, few educators understand information technology, and few information technologists understand education. There has been a fairly substantial development and successful application of some forms of computer assisted instruction, but nothing comparable to the development of applications of information technology in business, industry, medicine, engineering, or defense. It is going to take a very large amount of software development, oriented toward education and carried out by groups that understand both education and information technology, to create the essential base of educational technology.

In educational television, it has been clear for a long time that 'programming' is as important as cameras, transmitters, and receivers -- and very costly. In computer-based educational applications, there will have to be an analogous appreciation of the importance of 'programming' and 'application software'.

3.2 Until Recently, the Cost of Information Technology Was Too High for Schools

When the cost of a given commodity is halving every two years, it can be 'too expensive' in one decade and 'almost free' the next. That is what is happening to computer hardware, but not software, and not communications. During the 1960s and early 1970s, almost everything about information technology was too expensive to support any but the very 'cream' educational applications. Now computer hardware is affordable. It may turn out that there are enough dedicated people to get the software work done at not too great a cost. (The eagerness of dedicated people to work on the problem is one of the most favorable factors in the whole picture.) And it may be that satellites, cables, and optic fibres, together with computerized switches, will bring the cost of networks into the range that schools can deal with. Cost is still going to be a problem, but not as severe a problem as it has been in the past.

3.3 Many Schools Are Trying to Do Big Jobs with Machines That Are Too Small

Now that small microcomputer systems have become widely affordable, many schools are buying computer systems that are essentially hobby computer systems -- and expecting them to do big-system jobs. They sometimes come close to doing those jobs, but are not quite up to expectations, and there is a certain amount of disappointment. It should not be permitted to prejudice the future.

Actually, it is very much easier to develop successful applications on computers that are large enough to support comprehensive and sophisticated programming systems. Often, programs developed with the aid of such large systems can, when completed, run in small, inexpensive systems. However, it takes a lot of computer memory to support a sophisticated system of programs -- say 10 million bits of fast memory and 100 million bits of slow memory. It usually takes a sophisticated system of programs to make an application truly effective and easy to use. Experts can get by with less, but experts rarely need to. Users not knowledgeable about computers need 'friendly interfaces', and such interfaces require large memories.

As things are going, it may take about another ten years of continued technological advance to bring computers of the required capability into the present school price range. That is despite the fact that such computers are already judged cost-effective in many other application areas. What is out of proportion is school economics, not information technology economics. The problem is that schools are used to a pattern of big spending on people and buildings and austere economy on everything else. Educational institutions must change their economic philosophy if they are going to take advantage of information technology effectively and efficiently. It is saddening to realize that the future of education may depend so critically upon this consideration. The only thing technology (and the information industries) can do about it, if education refuses to alter its economic philosophy, is to outflank the shools by taking their case directly to the homes or by setting up technology based schools outside the established system.

3.4 The Basic Philosophy Underlying Most Applications of Computers to Education Has Been Wrong

The main thrust of computer applications in education has been to use the computer to push facts into students. The approach that works best, on the other hand, is to use the computer and auxiliary technology to create a stimulating learning environment and to make the computer a partner to the student in exploring and in solving problems.

Interaction with a well programmed computer can be strongly motivating to students. Actually programming the computer can be even more motivating. With the right set-up, even grade school children can program computers and, in the process, get excited about learning, and learn not only about computers but about the substantive fields with which their programs deal. There has been relatively little of this kind of application of computers in schools. Note that I say 'relatively little'. Some people have been working in this direction, and they are heroes. There are too few such heroes.

3.5 The Kinds of Information Technology Most Used in Schools Have Been the Non-Interactive Kinds

The main information technologies exploited by education have been Gutenberg, cinema, and television. One might mention, also, radio, phonograph, magnetic tape, and automatic test scoring. Those technologies are all non-interactive. The world of education is to be commended for its receptivity to those technologies and for its continuing development of educational television. Nothing that I am saying here is intended to diminish those accomplishments.

The hypothesis that underlies this paper, however, is that interaction is the powerful new force that offers the strongest promise of revitalizing education. That hypothesis may turn out not to be valid, of course. But there is now much evidence that a well programmed computer system that puts initiative into the hands of its users contains a large charge of motivation, and there is no doubt that people learn more when they interact with the subject matter than they do when they merely watch it. The motivational force of interaction seems even stronger than the attractiveness of television, even though there has been nothing in the computer field comparable to television's development of the art of creating program material that will boost the Nielson rating. In any event, the point here is that one of the shortcomings of past applications of information technology to education has been that the best-applied techniques have not had the motivating force of interaction and the participatory quality of interaction working for them.

4. THE NATURE OF THE POTENTIAL IMPACT: BENEFITS, COSTS, AND DANGERS

4.1 Potential Benefits

Let us suppose that, despite the present preoccupation with budget cutting and the continuing general reluctance to see the federal government undertake major initiatives in education in the United States, information technology nevertheless does get its big chance to revitalize education.[2] And suppose that it siezes the opportunity forcefully and also wisely. What benefits would be gained?

Consider productivity first. A large amount of our national failure to increase productivity from year to year is due -- obviously due -- to the fact that so much of the potential workforce is not educated or trained well enough to work productively. There is no question that, in many modern jobs, a poorly educated and poorly trained 'worker' can do much more harm than good. The economy is becoming increasingly a service economy, and services are composed mainly of -- not material, and not energy, thank Heaven, but -- information. So a real advance in education and training should give productivity a big boost, and that should give the economy a big boost.

Since productivity is a crucial issue, let me say five more short things about information technology, education, and productivity. First, it may not be a conincidence that productivity is falling just as the economy is becoming more and more heavily information-based. It may be that we have not yet learned to be productive in work with information, as we have in work with material things. Second, information technology is proving to be the best aid to increasing productivity even in fields, such as manufacturing, whose final products are material. Third, partly because of the sheer increase in the amount of information required by the society, and partly because of the need to deal with it more effectively, there is going to be an increasing need for people who understand the technology that deals with information. Fourth, education heavily supported by information technology is naturally going to be to a considerable extent education in information technology, and it will therefore have a natural pertinence to our needs as a society. Fifth, although many of us are dead sure that information technology is capable, through impact on education and training, to increase national productivity very significantly, we cannot lay out the argument clearly and forcefully enough to convince the people who have to be convinced in order to convert eagerness into action. We need definite and quantitative models based on solid analysis -- and presented with dramatic graphics -- to explain and convince. The present state of uncertainty and inaction is due, not to lack of care about our future, but to lack of real belief that information technology is the germinal force that can make it or break it and that education is the key field in which it must be put to work.

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[2] By 'get its big chance', I do not mean to limit the range of possibilities to massive federal support. One of the main concerns is whether the impact that information technology would have on education under the dominance of the forces of the marketplace alone would be better or worse than the impact that information technology would have on education under a national plan that merged government support with the entrepreneurial drive of the marketplace. I have an opinion about that, but I do not want to let it dominate this paper.

Closely coupled to productivity, but with a somewhat different connotation, is quality of life. Shortages of energy and raw materials may seem to threaten quality of life, but the universe of information offers an essentially boundless area into which our interests can turn -- into which, as some see it, our interests must turn. It may be a matter of practical importance to everyone, therefore, that we learn how to make exploration of knowledge as interesting as travel in foreign countries, that we learn to make the home information center a source of as much exhileration as 'four-on-the-floor' used to be. My own experience at the computer console tells me it can be even more interesting, even more exhilerating.

If the motivational power of interaction is as strong as I am sure it is, vigorous application of information technology to education will create a new regime in which, for millions of citizens, especially for the youth of the country, enthusiastic active involvement in creative activities will replace passive viewing and attending. To what extent commercial television is to blame for the general lack of feeling of well-being, for the prevalent anomie, I am not sure, but I think it would be a major benefit if education pulled a lot of people away from television. In any event, what a benefit revitalization of our society would be!

Coming down out of the clouds a bit to a level halfway between quality of life and productivity: Technology is capable of providing quality education to all citizens throughout the country. Technology can free the quality of education from dependence upon geography and upon affluence.[3] That is a matter of major significance to us in the United States because of our democratic political philosophy, but it is even more critical to people in the developing and the undeveloped countries because their entire populations are remote from the established cognitive centers of the world. If we developed a very effective and efficient technology-based system of education, we would have something truly valuable to offer them, something worthy of our tradition of liberty and freedom.

4.2 Costs

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[3] Note well that I am saying 'can', here, and not 'will'. Unless we plan it and force it to happen that way, the trend will probably go in the other direction. See 'Dangers', the second section following.

Education in the United States is a $40 to $80 billion per year industry, and to have a major impact on it will be expensive. The federal government will not have to fund the whole effort, as it did in the case of the space program, but as a practical matter it is clear that it would take a strong initiative by the federal government to activate a major program of application of information technology to the public schools. State and local governments are not organized to do it. Technology push and the profit motive might do the job eventually, but those forces are aiming themselves much more directly at the home market than at the schools.

A direct approach to estimating the cost of revitalizing education through application of information technology may be counterproductive if it comes up with large estimates. Moreover, estimates of the cost of applying information technology to education are likely to scatter themselves through a factor of ten. And I have no claim to expertise as a budgeteer. Nevertheless, I think that there is need for a rough guess as to what a major effort, built up over a five-year period and then continued for a decade, would cost. If I make one, it may stimulate others to adjust my guess. Surely the adjustment will be downward, for the general tenor of the times is incompatible with another space program.

Even having said that, I feel a need to waffle before facing the effort. No one in his right mind would embark abruptly, at the present time, upon a program comparable to the one that put men on the Moon in the 60s. A technology-based education program would have to evolve through smaller, pilot efforts.

For the sake of perspective on the long run, nevertheless, here is an estimate based on 'planning for success' and on the assumption that the first few years of gradual build-up confirm the most optimistic expectations:

Basically, any estimate is going to derive its size mainly from the fact that there are many millions of people who need improved education. Let us more or less arbitrarily take the number as 40 million. That does not quite include all the school students, and it does not include any adults, many of whom need retreading and/or continuing education.

The largest component of the cost would be the hardware cost. That is true, not because we are going to neglect software research and development but because the products of research of all kinds and the products of software development in particular can be replicated at very low cost, whereas the economics of mass production of hardware, though favorable, are not nearly as favorable. To get a ball-park figure on hardware, assume 40 million students and a $2000 capital investment in information technology per student. The image in my mind of what $2000 per student would buy is one that improves with time and approaches the set-up of the introductory scenario by the early 1990s. The investment would be programmed over a ten-year period, not beginning in an election year. $80 billion total; $8 billion per year. It would provide the hardware base for a very sophisticated and powerful educational 'system' for each student.

The most difficult cost problem would be a 'people problem'. Assume that there are 2 million teachers who should put 20 per cent of their time and energy into learning how to exploit the new technology. In the interest of keeping the numbers round, let us underestimate their salaries at $10,000 each per year -- of which 20 per cent is $2000. That amounts to $4 billion per year, $40 billion over the ten-year period.

The cost of software research and development is high, but, as mentioned, the cost of replicating a developed program is negligible. In educational applications, the ratio of use to development will be higher than it is in most applications of information technology. In order not to make the mistake of underestimating the software costs, let us assume, nevertheless, that 10,000 full-time professional analysts, subject-matter specialists, and programmers are involved in creating the software bases of the new systems and that 100,000 teachers and students are involved part-time. Let us allow $50,000 per year for each professional and $5000 per year for each part-time contributor. That makes the software cost come out to $1 billion per year, $10 billion for the ten-year period.

The sum of the three estimates is $13 billion per year, $130 billion over the ten years. But we should smooth the rectangle into a bell-shaped curve. There would be a gradual growth up to about $10 billion, then a rounded top that might reach $12 or $13 billion, and then a gradual drop off. Of course, if the program were very successful, further improvement would continue indefinitely, but the cost of it would be more than made up for by increased productivity, and the whole thing would be seen a a very different perspective.

Today, in the midst of budget cutting, $13 billion is a great quantity of money to contemplate spending on one program in one year. The natural first reaction is to reject the notion as preposterous or to start thinking about how to pare it down -- say to $13 million -- but even that sounds large in this building at this moment. In the perspective of the total cost of education, however, it is a relatively small amount, and in the perspective of the cost of welfare and unproductivity, it is even smaller.

Nobody knows for sure the cost of not revitalizing education in the United States. Superior education is probably one of the main factors accounting for Japan's remarkable economic advance. Inferior education is almost surely one of the main factors in our obvious decline. If we are going to pull ourselves out of the decline, we have to make the necessary investments in re-tooling our industry and in re-tooling ourselves. If we cannot invest in the technology that promises to get us out of trouble, we must expect to sink deeper into trouble.

My feeling about the cost estimate of $13 billion per year is that we should focus on it, or something like it, as a measure of what it would take each year over a period of years to revitalize ourselves informationally and intellectually -- and start getting ourselves into a position to see whether or not a program to develop technology-based education would actually work. The early costs would be nothing like $13 billion because it would take several years to get tooled up to spend money at that rate. Those years would provide time to develop a joint educational and technological capability and an opportunity to get some good measures of effectiveness and cost-effectiveness. But more about this in the final section.

4.3 Dangers

It is easier to do it wrong than it is to do it right. 'Doing it wrong', in the case of educational applications of information technology, might lead to indoctrination instead of enlightenment. It might lead to homogenation, with everybody being taught the same things by the same computer-assisted-instruction programs. It might lead to a general leveling, with everyone thinking the same thoughts in the same way. All that is quite the opposite of the ideal envisioned by people who have a notion of the benefits the new technology can bestow and who want to see it have a chance to fulfill its promise. There must be a strong and diligent effort to keep applications of information technology off the 'dehumanization' path.

If information technology comes to play a very major role in education, it will intensify the danger that education be turned into propaganda by governments or by powerful commercial or ideological organizations. A dictator could probably exploit the image of the computer as all-knowing and infallible. This line of thought makes me want to emphasize how important it is that both the human initiative and the computers in any future computer-based education system be distributed geographically. The role of central planning should be to ensure that the over-all system is coherent, that all the parts can communicate with one another effectively. There should be plenty of local initiative and control in all aspects that have to do with substance and content.

The easiest-to-develop techniques of computer-based education can handle facts but not concepts. Sheer exploitation of information technology, as distinguished from wise application of it, would probably lead to an undesirable shift of emphasis from concepts to facts. This is not a danger to be ignored, for, as suggested a moment ago, it is easier to exploit technology than it is to apply it wisely.

If techniques to simplify interaction with computers were neglected, the effect would be to limit effective use of computer-based education to the more privileged students with special training in the use of computers.

If information-technology-based educational systems were very effective but also very expensive, the effect would be -- in the absence of intervention by the federal government -- to limit the benefits to the affluent. Rich areas would have much better education than poor areas, and the disproportion would be worse than it is now.

There is a possibility that teachers may not master pertinent information technology. Some may be unable to master it. Others may be frightened away by preconceptions or bad initial experiences. Either way, an adversary situation within the educational community might result.

It is evident that industry is aiming much more at the home market than at the school market. Actually, although it is a great idea to make education entertaining, it is probably not in the interest of education to emphasize games and amusement as much as the home market has emphasized them. There is a danger in relying on education-in-the-home to fill the gap that that will be left by the schools if they do not greatly improve their effectiveness.

Finally, schools may not be able, as they are presently organized, to take advantage of information technology -- and they may not be able to reorganize themselves. If that turns out to be the case, and if information technology proves itself to be extremely effective in such other contexts as in-house educational and training programs in business, industry, and government, then commercial schools or other institutional alternatives to schools-as-we-know-them may spring up and siphon off the affluent students. That, of course, would intensify the problem of inequality of educational opportunity.

5. WHAT NEEDS TO BE DONE TO GAIN THE BENEFITS AND AVOID THE DANGERS

5.1 Getting Ourselves Organized

There are many intelligent and eager people out there who want to contribute to reversing the downhill trends of education and esprit in the United States. Some of them know education. Some of them know technology. Some of them understand other parts of the over-all problem: economics, law, sociology, demography, psychology, ... The first step in getting something started is to create the conditions under which those people will get together, get acquainted, come to understand the pertinence of one another's areas of knowledge, and form a community of techology-oriented educators. That is, indeed, a modest step, one that can be taken even in the middle of an economy wave.

The art of creating intellectual communities is not very well understood. It is clear that a lot of human interaction is required, and, until most people are on an electronic network, it is clear that meetings are part of the game. However, there is much more to it than just a series of conferences. A series of conferences, at this stage, might be destructive because so many people are cynical about the likelihood of any real program. What is needed, almost as the first toe-motion of the first step, are some definite plans and some visible projects aimed at carrying out the plans. These early-first-step undertakings can be modest. They need not total more than a few million dollars at the outset. The planning should be pluralistic and involve quite a few people, but it should happen quickly, and the time scale for moving into visible action should be short. Indeed, so much planning has been done during the last few years of relative research and development idleness that the main task of planning is to select from what has already been planned and firm up a definite course of action to get the work under way.

The early work should, in my judgment, be aimed mainly at getting the field's ducks lined up and demonstrating and augmenting the various approaches to improvement of education that appear promising. Not much effort should be devoted, at first, to formal evaluation. What we are looking for are approaches that work so well that their effectiveness is obvious. When we have some obviously good candidates, then it will be time to prove it formally and quantitatively. Moreover, the very early work should be viewed in large part as a community building effort. By 'getting the ducks lined up', I mean getting everybody acquainted with everybody else's techniques, building up the documentation and software exchanges, and getting at least the main research and development groups into electronic communication with one another. Finally, much of the effort of the first year or two should be devoted to getting the research and development onto a realistic equipment base. The technology of microcomputers and video disks, for example, is advancing so rapidly that it is foolish to be doing research with 16-thousand-byte memories and 'mini-floppy' disks. Before the research can be moved into application, much larger memories will be affordable. The equipment base for research should always be at least six years (and therefore at least a factor of 8) ahead of the current application equipment base.

5.2 Hardware Research and Development

Hardware research and development are progressing rapidly in the field of information technology without much support from education. Education does not need to worry much about hardware research. If education defines its needs, it will be able to use its mass purchasing power to influence the directions of technology development. It could, for example, accelerate the development of digital video disks. But hardware research and hardware development are not main areas of concern.

5.3 Software Research and Development

Two main branches of the software art are pertinent to education: system software (which is software that extends and augments the general capabilities of the hardware) and application software (which is software that performs functions that are meaningful in the perception of the people who want to use the system for purposes specific to their field of work). The education community can treat system software very much as though it were hardware. The community should define its needs and use its influence as a mass customer. Application software, on the other hand, cannot be developed without the direct participation of people who know and understand education as full-time professionals. Development of good application software requires the pooling of the knowledge and skills of experts in information technology and experts in the field of application.

The development of application software for education will come in two waves, one that will break fairly rapidly, and a second that will build up over several years -- perhaps even a decade or more. The first wave will focus on educational and informational techniques that are fairly well understood, and it will be mainly a development effort. The second wave will undertake the much more difficult task of reorganizing and re-representing knowledge in ways that will permit computers to be much more effective than they are now in helping people work with ideas and concepts. For some time, the second wave will be mainly a research effort.

In the first wave, several advances made in the 1970s will be adapted to education:

1. Electronic Message Systems
2. Editing, Formatting, and Printing Systems
3. Modeling and Simulation Techniques
4. Computer-Based Games
5. Data Bases and Data Management Systems
6. Computer Networks and Distributed Computer Systems

In addition, the first wave will be concerned with information technology that has been used in educational applications with some success but that needs to be further tested, improved, and augmented:

1. Computer-Based Drill and Practice
2. Computer-Assisted Instruction
3. Computer-Managed Instruction
4. Computer-Assisted Reasoning and Problem Solving
5. Business Games
6. Computer-Based Testing
7. Stand-Alone Teaching Machines
8. Pocket Calculators
9. Stand-Alone Electronic Games
10. 'Speak-and-Spell'-like Devices
11. Interactive Television

The first wave should, also, make comparative tests of interactive and non-interactive techniques to establish the true importance of interaction in educational applications. Among the non-interactive techniques, preprogrammed educational television and remote video lectures -- and, of course, books -- should be included. The need for such evaluative work is perhaps only to prove to all what is obvious to many, but the hypothesis that interaction is very powerful is basic to the whole undertaking, and it would be well to put it on the firmest basis.

The second wave will have to explore the many new possibilities that are being opened up for the representation of knowledge. We have lived so long with knowledge represented mainly in the form of natural language text, pictures, and mathematical expressions that it is hard to imagine that complex patterns of lists and pointers in computer memories may be much more appropriate for storing the world's corpus of knowledge. Nevertheless, the long-term future of education probably lies in new, computer-based representations of knowledge, and some of the most basic work of the second wave will be research on knowledge bases. Other topics that are important and promising are:

1. Natural Language Processing
2. 'Expert Assistant' Computer Systems
3. Computer-Based Tutorial Systems
4. Motivational Aspects of Interactive Use of Computers
5. Multi-Media Systems
6. Making Technology-Based Systems Easy for Non-Technologists to Use
7. 3-D and Other Spatial Presentation Techniques
8. Large-Screen Display Techniques
9. How Best to Adapt Computers to the Requirements of Various Subject Matters and How Best to Reorganize Subjects of Instruction to Take Advantage of Computers

5.4 Oversight

Whether undertaken as a planned program or left to the marketplace, the application of information technology to education will shape the future of life in the United States. It will be a process that will require wise oversight and wise guidance.

The application of information technology to education seems too crucial to be left unplanned and unstudied. We should try to foresee the opportunities and take advantage of them. We should try to foresee the problems that will arise and meet them head-on rather than being overwhelmed by them when they come upon us.

Committees of Congress should have definite assignments to monitor and guide the process and should be staffed for the purpose. Definite responsibilities of monitorship should be assigned to the Department of Education and perhaps to other agencies, such as the National Science Foundation. The main cognizant agency of the Executive Branch should maintain a list of goals and objectives and a list of dangers and threats. Indicators of the state of education should be developed and maintained in a consistent way over time. Every three years, there should be a report on the state of education and on progress in applying information technology to improve education.

Dr. **Licklider**. At this time we will hear from Dr. Maxine Rockoff, vice president, planning and research, Corporation for Public Broadcasting.

STATEMENT OF DR. MAXINE ROCKOFF, VICE PRESIDENT, PLANNING AND RESEARCH, CORPORATION OF PUBLIC BROADCASTING

Dr. **Rockoff**. Thank you. It is a great pleasure to be here, Mr. Chairman, and members of the committee.

Perhaps every extravaganza ought to have a wet blanket thrown on it for purposes of encouraging discussion. I will accept that role here this morning, Mr. Chairman.

There are four points that I will make.

First: I will say that I think it is unlikely that we will have a technology revolution in education. Moreover, I will argue it is not in the Nation's best interests to have one.

Second: I suggest there are less ambitious goals that we could adopt as a national policy. I will discuss universal computer literacy as one such goal. I will say that even this is too expensive in terms of the tradeoffs that would be required.

Third: We should settle for computer comfortable as a national goal.

Finally: I'll speak to the possibilities with respect to private sector involvement that could help make this an achievable goal.

With respect to my first point, that we are unlikely to have a complete technology revolution in education, I speak from 7 years of experience in another public sector, trying to introduce and to develop technologies for health care systems.

Although it may sound obvious, the technology has to be in the best interests of those directly involved in order for the technology to be adopted.

In one rural clinic in Oregon, we had nurse practitioners who were backed up by a physician 55 miles away. We had a two-way slow-scan television system installed that was relatively inexpensive and relatively simple. On its face, it appeared to be cost effective in that the cost of travel that was averted on the part of the patients from the rural area were more than the cost of the technology itself.

However, after the Federal funding ceased, the technology was removed. When we went back and asked why the technology did not become adopted, the answer in part was that the technology was not in the best interests of the people that had to adopt it.

The physician involved in the project was really not interested in saving patient travel. In fact, his interests were best served by increasing patient travel. He was looking to the rural areas because the urban community in which he was practicing was becoming tight with respect to an oversupply of physicians.

There are some other examples in my written testimony of technology not being adopted because it was not in the personal best interests of the adopters.

Now, what does this have to say for education? As Dr. Licklider, Mr. Melmed and Dr. Heuston have pointed out, education is labor intensive. It seems unlikely to me that teachers are going to adopt labor-saving devices.

Even if it were possible to have a technology revolution in education, would it be desirable in terms of the cost, at $13 billion for 10 years? But it is not just the capital costs; the opportunity costs must also be weighed.

If I had to choose as a goal universal computer literacy, which is even less than a complete technology revolution in education, versus traditional literacy or knowledge of history, I am not sure that I would opt even for computer literacy. In thinking about the absolute minimum I would ask for all Americans—I would say that it is computer comfortable. By that I mean the ability to interact with an inanimate but intelligent object or device comfortably.

To buy a fare card in Washington's Metro system today requires interacting with a computer, pressing the right buttons in response to step-by-step instructions. Today's Metro rider, however, still asks an attendant for information about routes and schedules.

It is quite possible, and even probable, that tomorrow's Metro rider will get information about routes and schedules by interacting with a computer. The level of computer comfort required is going to increase as the level of sophistication increases throughout society.

What Government actions and investments are needed to assure that all of our citizens become computer comfortable? Instead of taking Dr. Licklider's ambitious plan and scaling it down, which assumes that the full responsibility lies in the educational sector, I'd like at this time to take a different tack and come at the question from the perspectives of the user and the private sector.

First, there are important publicly supported experiments and demonstrations that lie outside the education system. For example, we at CPB are supporting a Teletext experiment in partnership with the National Science Foundation, the HEW telecommunications demonstration program, and the National Telecommunications and Information Administration to explore what kinds of public sector and private sector information could and should be provided to the home television set as part of the broadcast television signal.

We want to know what kinds of information the user will want in this form, whether it is information concerning the availability of services for the elderly, health-care tips, menu planning, television schedules, weather, or the like. Experiments such as these, including television, audio and visual conferencing, and other telecommunications and computer technologies are important if we are even to define what the potential for technology is, just as the experiments in technology in education were essential for defining the possible future that Dr. Licklider has drawn so excitingly. These, I think, must come from the public sector in terms of investment, and the proposal that we should make the software investment is, I think, appropriate and even essential.

But must all of the investment come from the public sector? I think the answer is clearly no. Major investments are being made in the private sector: the office of the future, electronic banking, airline scheduling, electronically delivered stock market information, satellite-based data communications, to name just a few.

In addition to the capital investments, industry is making significant educational investments to teach people how to interact with the necessary devices. Moreover, it is precisely these kinds of developments that make it important that we all be computer comfortable in order to have people that are able to use such machines and devices in industry in the future.

Now, should the entire *educational burden lie completely* in the private sector? Again, I think the answer is clearly no. What is the approximate mix, then, between public and private investment? I would like to suggest some possibilities.

I'd like to call your attention to a device with which you may be familiar. It is being marketed by Mattel, Incorporated. It is called Intellivision and it goes well beyond the by now traditional television games. By adding a computer keyboard, this product offers individualized tax preparation, stock analysis, astrological forecasting and guitar lessons.

Of greater interest to the participants at this seminar, this product also offers The Electric Company's arithmetic and spelling lessons for 7 to 11 year olds. The Sesame Street graduates, the 3 to 5 year olds, will be computer comfortable without even knowing that they are, in fact, interacting with a computer as they play these games. Small children will become skilled at interacting with an inanimate but intelligent device. I predict that such children will accommodate easily to more sophisticated information processing tools as they grow up. If technologies like Intellivision become widespread, they will go a long way toward assuring the minimum level of computer comfortableness that I am advocating.

The questions for the education professionals then become these. How can we take advantage of developments taking place in the private sector as information technologies are being adopted there? How can we identify and then prevent or ameliorate their many potentially harmful social consequences?

Dr. Licklider skimmed over the possible harmful consequences of a technological revolution in education. I think the dangers are going to be even greater if the profitmaking private sector drives the technologies. These are dehumanization, propaganda instead of education, emphasis on facts over concepts, and, most importantly, inequity. The less well off are going to need the Metro schedule and the information on availability of services for the elderly at least as much as the well off will need them.

In summary and conclusion, I have made the following points:

There is unlikely to be a technology revolution in education, given teachers' probable resistance to adopting teacher-saving devices.

Universal computer literacy would be one possible educational goal that would require a substantial investment, albeit a smaller one than would be required for a technology revolution.

For my part, I would settle for computer comfortable as a goal rather than computer literate, given the tradeoffs with other educational goals that would be required and given what I see as the needed minimum for every citizen, namely to be comfortable when interacting with an inanimate but intelligent device.

Finally, I see promising developments taking place in the private sector, such as cable-driven television learning, which make me optimistic about our chances for achieving this more modest, but still challenging and exciting goal.

Thank you very much.

[The complete statement of Dr. Maxine Rockoff follows:]

STATEMENT OF MAXINE L. ROCKOFF, PH. D., VICE PRESIDENT FOR PLANNING AND RESEARCH, CORPORATION FOR PUBLIC BROADCASTING

Mr. Chairman and Members of the Subcommittees, I am pleased to participate with you today in this panel discussion on Social and Economic Impacts of Information Technology in Education.

The potential for computer and telecommunications technologies to have profound impacts in education is clear. In addition to the interactive, computer-based technologies discussed by Professor Licklider, there are other technologies with such potential, including television as we know it today and as it is evolving in the changing telecommunications environment. Indeed, the Corporation for Public Broadcasting recognizes this and plays a major role in assuring that the educational potential of public television programming for learners of all ages is fulfilled.

However, the perspective that I wish to bring this morning is based on the seven years that I spent in the Department of Health, Education and Welfare developing similar technological innovations in a different public sector, namely health care delivery.

One of the most important lessons I draw from that experience is that the adoption of technology will not take place unless it is perceived by the adopters to be in their own best interests. Although this may seem obvious, I assert that it is not, and I will illustrate with three examples.

In one rural health care project we installed a relatively inexpensive two-way slow-scan television system between a rural clinic staffed by two nurse practitioners and a physician providing them backup in a city 55 miles away. The purpose of the system was to save time and travel costs for the rural patients and to improve the quality of the medical care they were able to receive at the clinic close to their homes. On its face, the system appeared to be cost-effective in that the travel costs averted exceeded the technology costs. However, the system was removed after the Federal demonstration funding ended. Why was the technology not adopted? In my view there was one discouraging but overriding reason: The system was not fundamentally in the best interests of the technology adopters. First, the physician's interests did not lie in saving patient travel to his office. Rather, he decided to participate in the demonstration because he wanted to increase the size of his practice, and his supervision of the rural clinic expanded his patient base. It was in his personal interests to increase patient travel, not to decrease it. Second, the nurse practitioner who initiated a teleconsultation was taking additional time to handle a patient she had already decided she couldn't handle completely without help. She could have simply referred the patient to the physician and proceeded to her next patient. Using technology inconvenienced her and required that she learn new ways to deal with patients; it was not in her interest to do so.

The second example is an urban health care project. A large university hospital was linked via two-way television to a small, inner-city hospital whose patients' fees were paid mostly by MEDICAID and MEDICARE. One of several applications of the two-way television system was its use for daily rounds in the small hospital's newborn nursery by a newborn specialist at the university.

There were approximately 500 births per year in the small hospital. The entire costs of the telecommunication system, including paying for the university's neonatologist, could be paid for by adding $10 to the bed-day charge at the small hospital for mother and infant. Based on the large difference in bed-day charges between the small hospital and the university hospital, one would still have saved roughly $250 per day in bed charges alone by delivering the normal baby at the small hospital, while maintaining contact with the university hospital so that transfer could occur immediately in those few cases in which complications arose. But who decides whether to adopt the technology? It is the professional health care providers at both hospitals--not the MEDICAID department. And again, it is not in the immediate interests of these professionals to save MEDICAID money.

In both of these examples the health care system would have to be restructured and the incentives of its participants changed in order for the technology to be adopted and the cost savings made possible by technology actually realized.

There is another health care technology, however, whose adoption was so swift as to be startling. I refer to the Computerized Axial Tomographic--or CAT--Scanner. There is almost universal consensus that this is a remarkable technology that has had dramatic positive impact on patient care. It deserves to be noted also, however, that a CAT-Scanner generates additional income in most of the radiology departments and other sites where one is installed. It is definitely in the adopter's self-interest.

What do these examples have to say for technology in education?

First, I think we must look closely at who must decide to adopt the technology and see whether it is in their own self-interests to do so.

Education is, as Dr. Licklider observed in his paper, highly labor-intensive. Thus, it strikes me that it is not in the fundamental best interest of the laborers--the teachers--to rush to adopt labor-saving devices. The organizational structure of the educational system and the teachers' incentives would have to change dramatically.

Second, there is a history of resistance to innovation in education, whether technology-based or otherwise. Given this and given the enormous capital investment required that Dr. Licklider has laid out, it is difficult to be optimistic about the prospects for a technological revolution in the educational system.

But what is it that our Nation needs? How important is it that a technological revolution in education takes place? Could we settle for somewhat more modest and perhaps more realistic national policy goals?

Computer literacy for all Americans would be a more modest goal. By this I mean that each citizen would have sufficient knowledge of computers so as to be able to use them effectively, know what they can do and what they cannot do, be cognizant of their potential for good and their potential for harm, and finally be able to think in algorithmic terms, that is to be able to analyze a problem into its component parts in a fashion that would make it amenable to computerized solution.

But there would necessarily be tradeoffs required--in terms of student time, teacher energy, and capital costs--devoted to achieving even this goal as against other educational goals, such as traditional literacy, knowledge of history, and so on. Speaking personally, I am not sure that we should commit to this goal if it will mean trading it for others because I think traditional literacy is, for example, an even more important goal than computer literacy.

Yet we know that computers will pervade our lives and our citizens must be able to deal with them. What then is the minimum level of computer knowledge that we should strive to make universal? I think it is "computer comfortable".

By computer comfortable I mean "able to interact easily with a computer". The level of sophistication required will vary for different individuals, and I think the minimum level is likely to increase as technology advances. To buy a FARE CARD in Washington's METRO today requires interacting with a computer, pressing the right buttons in response to step-by-step instructions. Today's METRO rider, however, still asks an attendant for information about routes and schedules. It is conceivable that tomorrow's METRO rider will get this type of information via computer interaction--much more sophisticated than the simple FARE CARD interaction universally required today.

As more and more computers enter homes and work places, our citizens will increasingly have to use them to send and receive information of all kinds.

What government actions and investments are needed to assure that all of our citizens become computer comfortable? Instead of taking Dr. Licklider's ambitious plan and scaling it down--which assumes implicitly that the full responsibility lies in the educational sector, I would like to propose a different tack and come at the question from the perspectives of the user and the private sector.

First, there are important publicly supported experiments and demonstrations that lie outside the education system. For example, we at CPB are sponsoring a TELETEXT experiment in partnership with the National Science Foundation, the HEW Telecommunications Demonstration Program, and the National Telecommunications and Information Administration to explore what kinds of public sector and private sector information could and should be provided to the home television set as part of the broadcast television signal. We want to know what kinds of information the user will want in this form--whether it is information concerning the availability of services for the elderly, health care tips, menu planning, television schedules, weatner, or the like.

Experiments such as this including television, audio and visual conferencing, and other telecommunications and computer technologies are important if we are even to define what the potential for technology is, just as the experiments in technology in education were essential for defining the possible future that Dr. Licklider has drawn so excitingly.

But must all of the investment come from the public sector? I think the answer is clearly no. Major investments are being made in the private sector--the office of the future, electronic banking, airline scheduling, electronically delivered stock market information, satellite-based data communications, to name just a few. In addition to capital investments, there are obviously associated educational investments in teaching employees and users how to interact with the hardware. It is precisely these kinds of developments that suggest that we should all be computer comfortable at some minimum level, so industry should be willing to assume some of the educational costs.

Should the entire educational burden lie entirely in the private sector? Again, I think the answer is clearly no. What is the appropriate mix, then, between public and private investment? I would like to suggest some possibilities.

First, I would like to call an interesting new development to your attention. Mattel, Incorporated is test marketing a new product called INTELLIVISION that goes well beyond by now traditional television games. By adding a computer keyboard, this product offers individualized tax preparation, stock analysis, astrological forecasting, and guitar lessons. Of greater interest to the participants at this seminar, however, this product also offers The Electric Company's arithmetic and spelling lessons for 7 to 11 year olds. INTELLIVISION is also being test-marketed for cable delivery of the software into homes. As 3 to 5 year olds graduate from Sesame Street, they will be computer comfortable.

Without even realizing that they are interacting with a computer, small children will become skilled at interacting with an inanimate but intelligent device. I predict that such children will accommodate easily to more sophisticated information processing tools as they grow up. If technologies like INTELLIVISION become widespread, they will go a long way towards assuring the minimum level of computer comfortableness that I am advocating.

The questions for the education professionals then become: How can we take advantage of developments taking place in the private sector as information technologies are being adopted there? And, how can we identify and then prevent or ameliorate their many potentially harmful social consequences? Dr. Licklider suggested many possible dangers associated with a technological revolution in education and many of them are even greater if the profit-making private sector drives the technologies. These are dehumanization, propaganda instead of education, emphasis on facts over concepts, and, most importantly, inequity; the less-well-off are going to need the METRO schedule and the information on availability of services for the elderly at least as much as the well-off will need them.

In summary and conclusion, I have made the following points:

- There is unlikely to be a technology revolution in education given teachers' probable resistance to adopting teacher-saving devices;

- "Universal computer literacy" would be one possible educational goal that would require a substantial investment, albeit a smaller one than would be required for a technology revolution;
- For my part, I would settle for "computer comfortable" as a goal rather than "computer literate", given the tradeoffs with other educational goals that would be required and given what I see as the needed minimum for every citizen--namely to be comfortable when interacting with an inanimate but "intelligent" device; and finally,
- Promising developments are taking place in the private sector--such as cable-driven television learning--which make me optimistic about our chances for achieving this more modest but still challenging and exciting goal.

Dr. **Licklider.** Thank you very much.

Next, Dr. Vivian Horner, vice president of program development, Warner Cable Corp.

STATEMENT OF DR. VIVIAN HORNER, VICE PRESIDENT, PROGRAM DEVELOPMENT, WARNER CABLE CORPORATION

Dr. **Horner.** I am very pleased to be here today and to offer testimony. A great deal of this is going to be redundant. It is amazing to discover that there are all these people who know the same things and tend to think in the same direction on a larger or smaller scale.

Les Brown, in his recent book called "Keeping Your Eye on Television," which I highly recommend, paints what I believe to be an accurate picture of our changing relationship with the television set. I quote from page 41:

> Dazzling new kinds of television are entering the picture, the gifts of an exploding technology. Individually or in combination, the electronic marvels that are now bidding for a place in the scheme of national and global communications could touch off a second television revolution or one that might deal a severe jolt to the existing commercial television system and profoundly affect the way consumers use the medium.
>
> Through these new delivery systems with their special components and antennas, the ordinary television set may take the place of the bygone neighborhood movie house and could become an extension of the opera house, football stadium, library, university classroom, church, town council and the hospital emergency room. We can foresee these sets serving as a burglar and fire alarm system, a home computer and a receiving unit for electronic mail.

It sounds like tomorrow, but it is today. It is growing. That is the most fundamental fact that we, as educators, must recognize.

I've been associated for the past 4 years with an innovative, interactive cable television system in Columbus, Ohio, called Qube, which allows subscribers to participate directly in what comes over their TV screens. They push small buttons on a small home console. Qube has been variously characterized in the media as "talkback TV," "participatory television," "the ultimate democratic tool" and "two-way TV." By whatever name, Qube is an operating business, now over 2 years old. The vision suggested by Mr. Brown is an everyday reality. The subscribers have the choice of viewing uninterrupted movies; watching the OSU-Purdue football game without commercials; participating from their homes in a book club discussion of Follett's "The Eye of the Needle;" taking a course for credit from home; asking and answering questions via the home terminal or via telephone; attending a community planning board meeting and letting their views be known without leaving their living room. And while they are doing any of these things, or even while they are not at home, the same computer that makes these video options available is monitoring burglar, fire, and medical alert systems in their homes.

As Professor Licklider pointed out in his very thoughtful assessment of the impact of information technology on education, it is the confluence of computers and communications that is at the heart of the changes that we are here to examine.

In my own professional area, the use of television in education, this confluence has extraordinary implications. During my 5 years as director of research for The Electric Company at the Childrens' Television

Workshop. I believe that I came to understand what broadcast television, at least as an educational instrument, can do and what it cannot do. Breadth of reach and commonality of experience are perhaps plusses of television as we now know it, but ultimately I feel that broadcast television has two telling shortcomings: First, that it is a medium of scarcity—that is, access to broadcast time and space is severely limited; second, it is one-way—that is, the educational broadcaster can only control the audiovisual stimulus which is only one crucial factor in learning. I look to the emerging electronic technology to go beyond these limitations.

Cable technology, and perhaps direct satellite-to-home transmission, will provide a solution to this scarcity problem, offering tens and possibly even hundreds of channels of program potential to each home as the delivery technologies become more widespread. As has been the case with Qube, the availability of many channels has made possible the exploration of new ways to bring education to people in their homes, with college-credit telecourses, self-instructional programs, continuing professional education, lecture series and special needs programming regularly available. More importantly, the pairing of computers and cable has created the possibility for educational television to be a two-way process.

On this one point, I differ with Professor Licklider. I believe there is ample evidence from research in the psychology of learning to indicate that interaction is a vital ingredient in the learning process. I would not recommend extensive financial resources be allocated to investigate whether interaction is important, but only that funds be allocated to determine the kinds of interactions which are necessary to create sound learning, utilizing the new technologies, and to create and sustain environments that can maintain the results.

In the next decade, I believe that we will see personal computers in most homes, just as we now see small electronic calculators in the hands of everyone from second graders to senior citizens. It is likely that this proliferation of small computers will happen in the private sector at a pace that is more rapid than we will see in the adoption of the new technologies by schools. A democratization of the learning process is likely to occur. Indeed, it is occurring. Whether or not the schools, as we know them, adapt their structures to accommodate this process, it will, nonetheless happen. People will increasingly have control over what they learn, and how.

As Professor Licklider has pointed out, and I would like to underline, that in addition to considering public policy issues in an information-based society, the single most vital problem we face is in the software, the creation of appropriate learning materials for individual and small group use and the creation of settings in which appropriate interactions can occur.

Our society traditionally is willing to commit billions of dollars to the creation of hardware in the belief that, somehow, the answer to all our problems lies in the better mousetrap. Yet, the humane use of that hardware to solve our human problems has never greatly absorbed us.

As the ever-increasing pressures of the energy crisis and a world in which there are few secrets closes in on us, we have an opportunity to do some intelligent advance planning. Communications will come to replace many of the energy- and material-based functions of our society, as Professor Licklider pointed out. I believe the technology will take care of itself and the economics of the marketplace will see to its rapid spread throughout the society. But a major and sustained effort will be necessary to insure quality and coherence in the educational uses to which this technology is put. The British open university experience may offer us an instructive example. They recognized that public broadcast television could bring one kind of experience to many individuals at once, and thus be very cost effective. They also recognized that television could not do the job alone. Appropriate print materials, regional tutoring centers, uniform accreditation procedures, a tight line on quality, all contributed to the success of the British open university.

We will need to plan similarly. We must create a pool of people who understand the new technologies, as well as the needs of education. We need to divide the learning process into those features which lend themselves to interaction with the technologies and those which do not, so that learning networks can be made functional and the necessary roles of people defined. Above all, appropriate learning materials, video, audio, print, computer software, and so forth must be collated and created, and people trained to access and use those materials for creative problem solving.

"Schools" need to be thought of in a broader sense, as facilitators of the learning process rather than as primary locations for it. Like an extension of the open classroom concept, educational institutions will need to recognize that learning occurs in many places and in many ways. The task of those institutions will be to insure that the sequence and quality of learning experiences are right and that learning for the individual has indeed resulted in a specified degree of mastery.

The new electronic technologies are likely to play a very central role in this evolution, as the home becomes, among other things, a primary learning center.

Thank you very much.

[Applause.]

Dr. LICKLIDER. Thank you very much.

That was very helpful and very good.

Next, we have Dr. James Johnson—who has the only university job worse than that of dean—director of academic computing, at the University of Iowa.

STATEMENT OF DR. JAMES JOHNSON, DIRECTOR, ACADEMIC COMPUTING, UNIVERSITY OF IOWA

Dr. JOHNSON. It's a pleasure to be here to address this audience and this distinguished panel and the Members of Congress.

I was going to warn you that I am part of the enemy, being from a computing center. I think that I have something on my wall that says that every faculty will gladly hang their computer center director if only they could agree on the time.

I am not totally the enemy, however. I guess that the work I am the proudest with is my work with CONDUIT, which is an effort to disseminate computer-based instruction materials in higher education. Today, my focus will be on higher education. Since I am an enemy, I'll wear the computer center hat rather than the CONDUIT hat. First, in terms of talking exclusively on higher education, I think things are quite different there than they are in the rest of education. In higher education, technology is not widely used in instruction today.

In fact, in a survey that we did a couple of years ago, we found something like 60 percent of the departments of biology, mathematics, physics, and chemistry made no use of the computer in undergraduate instruction at all. Where the computer is used in instruction, 40 percent of the time it is as a tool or object of study. It is not used as a delivery mechanism for instruction; it is used to teach programming; it is used to teach data analysis; it is used in information searches. But it is not widely used in instruction.

Nevertheless, I would like to say that, in the next decade, use of computers in higher education is going to increase dramatically. The reason it is going to increase dramatically probably doesn't have much to do with instruction. I think that instructional use will occur through the back door for reasons that I will mention later.

The reason growth will occur is that, first, it falls on higher education to train people for use in industry and to develop new research techniques and new methods. Speaking of the training business, I don't think that is necessarily what a college or university ought to be doing, but they are doing it. We produce people that have to go out on the first day and be a teacher. We do produce people that, supposedly, walk in and they suddenly can be an engineer after they leave their institution of higher learning. I think that the rest of the economy is going to put very heavy pressure on higher education to train the people in using computer technology.

There is another reason why computer use will increase dramatically: Unlike elementary and secondary schools, attendance in higher education is voluntary. It is a decision that is made by the learner—so, the focus can be on the learner, not instructor, when you start talking about change. A person can choose to go to school or not go to school. There is a very great concern in the schools of higher education today about the fall of enrollment. Part of that is due simply to demographic data that says that there will be less students of college age. A lot of that is also because of the loss of confidence in the colleges and universities and a lower propensity of students to go to college. Students are going to demand new technology, and colleges are going to have to provide it.

The other thing that I would mention is that the colleges and universities have a great deal of competition in research. In one way, shape or form, research results are measureable. That forces instructors and researchers to go out and get the funds or to find the money to provide themselves with the latest technologies so that they can keep competitive and current.

Last, but not least, in higher education, unlike elementary and secondary education, people can get computing by themselves. You can go out and buy 15 Apples, as noted in an earlier talk; it seems that every laboratory in the University of Iowa has a microcomputer. It is for data gathering. So computer technology is there now. A lot of estimates of computing on the university campuses point out as little as a third of the expenditure is actually explicit. That is, only a third of it shows up in the budget for computing. The rest of it is hidden away in departments and in departmental purchases, and so on down the line it occurs outside the system.

What does this all mean? I'd like to say that the cost would be decreased for computing, that we would spend less money on computers and cover all this dramatic increase because of the technology that is changing or because we have increased productivity. I think computing costs are going to increase in higher education very dramatically as well.

Let me give you one example why I think costs will increase. A lot of people in engineering today are saying that we ought to provide our students with computers for computer-assisted design capabilities. That is an exceedingly expensive resource. It is well justified if you are at General Motors designing an automobile or at Boeing designing aircraft, or if you are in an architectural firm. You can justify it because you get your car on the market sooner. It takes less time for development. But, in education, if you introduce this, what cost have you reduced? You've reduced none. It is an add-on cost. It's an increase in the cost of doing business. It is an increase if you want to provide that. There is no corresponding increase in productivity to the educational institution itself. There may well be to society. I think that this is one reason costs will increase.

The second reason for higher costs is, if in fact we do increase the use of computers in instruction, there is going to be a heavy startup cost, no matter what. As an investment, this requires capital and labor expenditures initially that will gain savings over their life. If these returns take a decade, the investment today is not going to give us any cost savings in the next 5 to 10 years. We have no mechanisms for self-investment.

A third reason why the cost of computing will increase the cost of higher education is simply that the structure of higher education changes. Business schools and computer science departments are growing, and the schools of art are declining. In computing you have to increasingly compete for the faculty members with the outside, so it is very difficult today for a school to hire a computer scientist. It is also very difficult to hire someone in the business field with an information science background. When you hire them, you pay them twice as much as a professor of mathematics. It is caused by the outside competition for skilled levels. That also increases the cost of doing business by increasing the cost of faculty in information areas that are expanding.

Finally, in terms of increasing cost, we start talking about accessing information throughout the world rather than locally. Then that suddenly becomes an external cost to the institution; they must take money out of their pocket and pay somebody with real dollars. There will be some cost saving but on balance we will have greater resources at greater cost. Heretofore, most colleges and universities have been relatively self-contained. Not much money has gone off the campus. To do something new we have the faculty work an extra 4 hours. The external aspect of having to go out and get resources from other places rather than from a "free" labor resource or a cheap labor resource will increase the cost of education.

I believe that this is all going to occur. I believe costs will increase whether the Government allocates funds at all. What is going to have to happen is that the colleges and universities are going to have to cope with the increased costs that they dedicate toward information technology. How are they going to cope with that increased cost?

First, they are going to have larger courses; larger, larger, and larger courses. I see this happening time and time again.

The second thing that is going to happen is that there is going to have to be more specialization within the institutions. The single university that tries to be all things to all people is not going to be able to survive in that mode. Increasingly, colleges and universities are going to have to then specialize. Some will produce the engineers. Some will produce the doctors. Some will do something else. This is simply because not every institution will be able to make the large investment in the people and equipment necessary to provide a broad-based education.

There will be other cuts. There will be cuts in the arts; there will be cuts in the languages; there will be cuts in history. Because the money is going to go into computing.

Finally, administrations will institute electronic offices to get increased productivity in the institution to help fund what we will spend on the new technology. We will also save costs in instruction. We will make it cheaper to instruct students. I think that this is going to happen by the use of the information technology itself. I don't think the results here are necessarily going to be good. We are going to implement the worst example of computer technology to solve our problems very quickly by reducing costs. We will put in the computers to help students pass tests and we will forget about whatever else is going on in the educational process. This may seem pie in the sky, but it has happened. It is happening right now.

At the University of Iowa, there is a course in medical terminology, Latin and Greek. It has virtually no instructor and no class meetings. It is all computer-assisted as an approach there with testing at the end. They run something like 200 of the students a semester through that particular course. This may be appropriate for this course, but is it for all?

Last, but not least, we will finance the new technology with higher tuition. I think that all of these things have a potentially disastrous effect.

On the other hand, can we delay the application of the new technology? I don't think we can. I think the biggest crisis that we face in education generally, specifically in higher education, is loss of confidence. Employers are mad at us because we don't train people the way they want them trained. Students get mad because they can't get jobs. Most importantly, the educators themselves are sitting back and saying, "We're spending all this money for computers. What happened to traditional arts?" I think that this loss of confidence becomes serious. It goes much beyond education.

I get particularly irritated when I go to my kids' school. I think a lot of you do as well. We have a computer in our house. I think that we have a very rich learning environment. I go to work and find office automation and word processing systems. I have a terminal on my desk. I walk into my kids' school and it looks like it is something out of the 19th Century. I say, "Why can't we do any better than this?" Maybe I've got it wrong.

One thing that I've been doing for the last month is taking every assignment or exercise given to my children and putting it on a personal computer in my house. This is the easiest and most trivial application of instructional computing I can think of, but it is the level of what is done. So much more is possible. I think that we all feel this way.

Then we start asking questions. We start saying, "Well, couldn't we, as a university community, spend more money on education? We can go out and vote and spend more money on education?" What happens then? The state says, "You can't spend any more money on education." We have equalization laws. Every district has to spend approximately the same sum of money. If you want to spend more, State aid then goes down. There are a lot of pressures to prevent you from making changes. This reflects on our Government because education is perhaps one of the first places where we all deal with government. This is a very serious personal concern that I wanted to share with you.

I was going to say something about long-term impacts. I won't. I think it is most appropriate in talking about the long-term impacts of computing to not have computer scientists or economists talk about it, but to have artists and poets and novelists. Unfortunately, if we keep going the way that we are going, we are not going to have many artists, poets or novelists to tell us how things are going.

The point I did want to make about the long term is we no longer can project from the past in talking about the future. Enough forces are coming together such as computing and communication, and enough things are against the grain of what has happened over the last century, that we are talking about a total discontinuity. What is against the grain is that we for years moved to mass culture, mass production, urbanization and centralization—well, read the new book that is called "The Third Wave" which talks about the movement to the electronic cottage and what potential that has for fragmenting our society and for changing trends. It is not a straight-line projection from the past.

Well, I think my time is up.

Thank you very much.

[Applause.]

[The complete statement of Dr. James Johnson follows:]

SOCIAL AND ECONOMIC
IMPACTS OF INFORMATION
TECHNOLOGY ON EDUCATION

J. W. Johnson
Weeg Computing Center
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Introduction

Information technology can potentially provide us with the tools to greatly expand our intellectual productivity. It also has the potential to reshape our basic social institutions. To date it is widely used in industry and government to enhance the capture, transmission, and analysis of data and to allow the design and production of a wide variety of customized products. But information technology has done little to change the character of these institutions. Ironically in education where information is the essence of the process, its impact has even been smaller; outside of a few areas of research where it has changed modes of inquiry and a few courses of instruction where it is the object of study, information technology lies as a sleeping giant.

Despite the relatively mild impact of information technology to date, many students of society and technology are convinced that it is an irreversible force to be shaped, adapted, and harnessed, but not to be stopped. Many patterns are now emerging that point to significant qualitative changes in the way we think and live. Thus, there are two challenges to face. The first is to effectively use information technology in our educational institutions to improve the quality of education. The second is to anticipate the long-term impact of the new technology so that we can face today's decisions with the future in mind.

The short-term impact of the new technology on education is relatively easy to discuss. We can make qualitative predictions about the future; computers will be 32 times more powerful, several million homes will have information communications centers. It is much more difficult to assess the meaning of these changes and their impact on our social, political, and economic institutions because quantitative predictions look for continuities; they are projections of the past. Qualitative predictions look for discontinuities--things that are changing, never to be the same. The trick is to identify which of the myriad changes fit into a pattern and make them harbingers of the future. Perhaps this is a task best left to novelists, poets, and artists.

Although I'm not an artist nor a poet, I think I can see some patterns emerging that suggest dramatic changes in education and society in general. But my view is limited because it is focused on higher education and because it is colored by an orientation toward computers and communications technology.

The Short-term Impact

The Present Situation

The impact of the new technology on education over the next five to seven years is best seen by looking first at the current situation. The use of information technology at all levels of education lags far behind its use in industry. In higher education, for example, computer technology is seldom used for teaching, drill and practice, or simulation. When used, it is used to teach programming, analyze data, and solve quantitative problems. Even here, where there is little debate about the value of technology, use is such that about 60% of all science departments report no use or infrequent use of computing in undergraduate instruction. The clear result is that students are not being taught essential skills that are required in the post-baccalaureate world. Because the application of technology is cumulative, this gap is likely to increase in the next few years.

Why there is a serious lag in using the new technology as a tool to solve problems in education is illustrated by computer-aided design. Computer-aided systems for the design of ships, aircraft, automobiles, electronic circuits, and the like greatly reduce the time and effort necessary to produce a prototype. Consequently industry can justify using expensive hardware and software products and paying high prices for those products; a multi-million dollar system used by a few engineers is not unusual. Since computer-aided design systems have revolutionized the process of designing products and almost eliminated the drafting board, there is a demand to include computer-aided design in the university engineering curriculum. To support such a system would cost several thousand dollars for equipment per student. There are few balancing cost reductions. This problem is repeated over and over again in several disciplines, in research as well as teaching. If, for example, we provide a researcher with an electronic office that results in greater research productivity, few additional dollars flow to the institution as a result of that productivity. The problem here is not one of incentive or inertia but lack of funds.

Using information technology as part of the learning process itself is more complex although it does promise cost displacement. Professor Licklider has more than adequately addressed this problem for all levels of education but let me underscore the importance of incentives, software, and knowledge. There are few incentives to improve teaching even if we could measure its improvement. Software that goes beyond a trivial use of the technology is lacking, and it is unlikely that the private sector will produce it. Also the knowledge base necessary to apply the new technology to learning has yet to develop. This gap should not be surprising; after twenty years we are just now beginning to understand and improve information structures and programming activities.

Changing the Situation

Within existing institutions of higher education there are several things that can change the present situation. In some areas such as engineering where incentives now exist to use the new technology, funds for equipment or gift incentives are needed. If we assume that the current base of computing as a tool must be doubled, the bill is about 500 million dollars a year for higher education alone. Research is generally responsive to grant opportunities and thus can be directed toward use of the new technology across several disciplines.

The use of the new technology in instruction is a more difficult problem. Here incentives for change are slight, and where they exist there is a need for training, software and equipment. To meet these needs people involved with the new technology need to spend about one-fifth of their time in education and training for teaching. The bill would be 1 to 2 billion dollars a year for higher education alone, assuming equipment and incentive exist.

In the next few years the new technology simply increases the cost of doing business. In the short-term there are no offsetting costs because it will be several years before the economic benefits will be realized. It is ironic that education, an investment with exceedingly long returns to society, has no mechanism for investing in itself.

Results of New Technology

In looking at the short-term impact of the new technology, I'm assuming that educational institutions must employ the new technology as a tool and as an object of study. These uses will occur in higher education because those schools that don't use the new technology will find it difficult to attract students and researchers, particularly in fields that require high technology.

In the short-term the new technology is likely to be quite disruptive to all of education and particularly higher education. Colleges and universities face increased costs of education in providing their students and researchers with the tools of the new technology. To the extent that new funds are not available, resources must come from cuts in other parts of the institution. The results may be larger classes; more specialization in fewer courses of study; fewer faculty in the arts, languages, and history; and higher tuition. There also may be a drive to use the new technology to reduce clerical and instructional costs.

Because these changes will be painful and not always wise, they will be resisted. This resistance, along with the lengthy time needed to effect changes in what is basically a political institution, will add to loss of confidence in higher education. Employers will be dismayed about lack of skills of graduates, students will find it difficult to get jobs, and newly emerging competitors will convince some people that they can educate better with the new technology. Educators themselves will correctly question whether all this emphasis on technology produces better people.

This loss of confidence in educational institutions is more pervasive and serious than most people realize. With the new technology the private sector has entered the educational market, and no one has yet devised a better system for disseminating innovation than our market-based system. The family with a personal computer, a video cassette player, and access to information banks throughout the country is going to wonder whether they can provide a better education than the school system. And so will the family that can't afford these things. Since education is for the most part a public good provided by government, this loss in confidence will not likely be restricted to schools.

Long-term Impact

Beyond the near term, the new technology promises significant changes in our institutions over the next generation. Changes in education will reflect the broader societal patterns of change.

In Society

The common feature of all the new technologies is that they put more power and control into the hands of individuals. Videotape cassettes, community communications cables, information utilities, telecommunications, videodiscs, and personal computers give individuals a much greater choice of the content, place, and timing of information flow. Such devices offer the possibility of personal interaction and can be customized to an individual's style. They are a force that opposes the established trends of mass culture, mass production, mass communication, and urbanization. If this new force is combined with the trend toward having the work force deal with information rather than materials, our activity centers can be located anywhere. The leading edge of this change is seen in the growth of population in the sunbelt in recent years, made possible because modern industry does not need to be located near its source of raw materials. Because of mass communication it's no longer necessary to live in a major metropolitan area to be aware of the latest fashions, news, and culture. This shifting of our population is likely to be accelerated in the coming years.

The next step will be to move the workplace to the home or, as some have called it, the "electronic cottage." If a significant portion of our population is able and willing to work at home the whole economic, social, and political fiber of our society will change. Some industries such as the auto and oil industries will decline; others such as communications and electronics will thrive. Communities will become smaller and governments may become more fragmented.

In Education

The increased importance of information and intellectual activity and the need to help people adapt to change places a heavy burden on education. Not only do we need to teach new skills to new groups of people, but we need to teach with the new technology. Education will constantly need to balance new needs against its traditional role of transmitting our culture to new generations. Education will be more crucial, and but it will come in a variety of forms from a variety of sources.

In education these long-term changes will be noticed first in colleges and universities because they are voluntary and centralized. (In many ways the size of the market makes elementary school a better target, but here we are likely to have alternative schools rather than new structures.) Colleges and universities will produce more courseware and perform less instruction. Measurement and testing of educational accomplishment will become critical. Resident programs will become highly specialized in institutions and perhaps more elitist in selecting students. Credit through testing will be common and will open the way for the private sector to provide education as well as training. The questions raised by these changes will be many and serious. The answers and the questions aren't now known, but if the past is any indication we will learn considerably more about education than we know now.

Conclusion

In the short run the nation needs a massive effort to educate people to use new and existing information technology. The cost of not doing so is lower productivity, higher training costs in industry, government, and the military, and loss of confidence in our institutions. The cost of upgrading use of instructional technology will be several billion dollars a year for higher education alone. This effort will be disruptive as costs are cut in other places to meet the new needs.

Long-term changes resulting from the new technology are likely to be sweeping but their exact impact is almost impossible to assess. For every desirable turn things could take, there is at least one undesirable outcome. We could have the most productive, egalitarian, free, humane society ever imagined by man, or we could be reduced to an undisciplined, fragmented, selfish group of individuals.

What can we do about something that is difficult to predict? Minimally there must be a constant asssessment of the impact of the new technology on education and society and a public policy for dealing with resulting changes. Quite simply the potential for change is so great that we must become more future oriented. More ambitiously we need pilot studies to assess the impact of the new technology before it occurs widely, and we need a better measurement of what we are doing now so we can properly assess the impact of change.

The future of education, and indeed of our society, demands that we make the effort to channel the tremendous potential of the new technology to humane ends.

Dr. Licklider. Thank you very much. Now comes your chance, the chance of you participants who have been waiting impatiently to participate. I think that I will remind you that the rule is first to identify yourself—give your name and your affiliation. Speak clearly because the acoustics are not the ultimate in this room.

Dr. Bork. I am Alfred Bork, Educational Technology Center, University of California, Irvine. I think that I would certainly agree with the fact that many speakers have focused on the problems of curriculum development. That is, if we are going to move into any of the types of futures, that were projected, we are going to need considerable development of curriculum material Arthur Melmed started with that and it has been the theme of many of the other speakers.

The question that I would like to raise with people is what are our chances of obtaining extensive funds for curriculum development, either through the Government or through some sort of combination of Government and commercial concerns? The truth is that, after the very large push in developmental activities that happened in the sixties, the Federal Government almost withdrew from it. There were reasons for that. There were developments that got severe criticism in the Congress. There were other developments that misjudged students, and so forth. I think that we learned something from that. It does seem critical for the future that we have some coherent development of full courses that involve a computer as an integral component and involve all the other types of technology that have been talked about.

What are our chances of persuading the Government that this is necessary?

Dr. Licklider. That's certainly a good question. I don't know whether there's going to be a good answer. The floor is open to one if there is one.

[Pause—no response.]

Dr. Licklider. I think that the ball has been pitched but neither hit nor caught.

Now, the gentleman in the fourth row is next.

Mr. Levy. My name is Allan H. Levy, University of Illinois, School of Clinical Medicine, Urbana, Ill. I wanted to ask a question about the increasing confluence between communications and computers. I have some modest familiarity with the PLATO system, I am currently looking at it in terms of the medical community. There is a very widespread use of the PLATO system.

We've seen the emergence of a community of students and some faculty who talk with each other around the country on topics such as the role of women as a gynecologist, and other matters relating to social medicine. I have some difficulty now in persuading some of my associates that this, essentially, is an important part of the educational process.

I wonder if there are any ideas as to how we could evaluate the effectiveness, in professional education, of what I see as a tremendously useful tool in professional development?

Dr. Licklider. I knew it wouldn't be long before we had a call for an evaluation. I think the education field has learned to ask the question: What percentage of improvement does this provide? Even before the question, how much does it cost? Are there any ideas about evaluation?

Dr. **Horner**. I've been involved, over the last few years, with several attempts to use cable television for continuing professional education. There are some efforts to get a continuing educational channel up on the satellite, such as professional education. I think, probably, the real question here is one of convenience.

While the PLATO system is a highly sophisticated means for connecting people with one another in a professional sense, I think it isn't so much a question of is this valuable or not. It is really a question of whether you can get done what you need to get done and learn what you need to learn, and get properly accredited for it.

Without any evaluation there are professional groups moving into the accreditation of courses taken in this fashion. The American Medical Association will be in fact giving continuing education or units in continuing education acquired in a variety of ways. So, on the question of convincing your colleagues—if they find that, instead of schlepping out two nights a month for continuing medical education in a city that is 35 miles away, they could stay at home and do the same thing and be properly accredited—it will happen anyway. You won't have to convince them.

Dr. **Licklider**. Thank you. Go ahead, Maxine.

Dr. **Rockoff**. Just one additional comment.

In evaluating the technology it is important to assess who pays and who benefits. Again, using examples from the medical system, if a system is cost effective from the point of view, say of Medicaid saving money, and if the people that have to use the technology are not, themselves, motivated by saving Medicaid money, then that becomes a barrier to the widespread adoption of the technology. It is important in the evaluation to look at who is paying for the introduction of the technology and who is benefiting from it.

Mr. **Beder**. Harold Beder, Rutgers University. A lot has been said here today, both implicitly and explicitly about how educational technology is going to fit into the educational system. Little has been said as to how educational technology may, in fact, change that system. I am very interested in asking Dr. Licklider, regarding the Cheryl scenario, what purpose the public schools, as constituted today, might play in the scenario? It seems to me that Cheryl could do her thing in her home, the local library, or virtually anywhere, as well as in something called a school.

Dr. **Licklider**. I agree there certainly is that potential. I think, however, that there has to be a lot of social support, including face-to-face social support, in order to get those things going. I believe in the distributed intellectual community, in the idea of working groups distributed around the country—but I think that they have to have some face-to-face meetings first in order to get acquainted, to establish rapport. Otherwise, the thing may never get off the ground.

I think that the school is a pretty good place for all of this to happen. I suspect that if the school is not receptive but hostile, and if the technology really does prove to work very effectively, then there will spring up commercial schools that will be somewhat exploitive, but will give to the affluent students an opportunity to take advantage of the technology. I have the feeling it would be bad for society to have an inequity in the distribution of educational technology. I think it is only a third possibility that the application of information technology to education could take place in the home. It is so obvious that the home use of electronics starts with amusement, entertainment, and games. It only gradually migrates to education. The school has a tremendous advantage of starting off at least with the established purpose of educating people.

Dr. **Johnson**. I don't think there is any question about that. I think this is true in higher education. I think what was touched on a minute ago is that the whole idea of the certification and granting of degrees, is critical to the whole process. That is why testing and the controversy surrounding testing is very important. What we do in higher education and all education is that we control the accrediting process and the degree-granting process. The minute you take the control out of the hands of education or have a continuing education credit or college equivalent credits, then you grant the option for the private sector to enter the market or for people to do it on their own at home. I think that would change the role of higher education. We will be less deliverers of instruction and more producers of instruction.

There is an awful lot that we have to do about changing some of the laws and regulations that govern activities of nonprofit organizations in terms of the sale of services, that is, if we will tackle this problem.

Ms. **Stager-Snow**. I am Dania Stager-Snow, Graduate School of Education, Rutgers University. Cultural diversity was mentioned, and it is implicit in many of the messages. Dr. Horner mentioned democratization, but I do not see that democratization will occur across classes. I feel that technology will increase the gap between lower and upper classes. I feel that Dr. Johnson also is dealing with that when he talks about excess cost. My real concern is how is the technological revolution going to handle cultural diversity? It is not a question that is easy to, or that I expect you to answer.

Dr. **Johnson**. The point I was trying to raise was to get that sort of response from you and other people. I'm very concerned about the fact that I deliver a large portion of the education for my children in my home. I have much greater capacity to do it than a lot of other people. I think that is a critical problem.

I think when people talk about adding diversity they are simply saying that this technology allows for greater individualization of what you're doing. I think that is clear.

Now, how we extend those benefits to all sectors of society is another question. I can't answer it. I hope to raise it. I am glad at this time that you are responding to it.

Dr. **Licklider**. Thank you for your treatment of this problem. I am glad it was definitive and conclusive.

We have now come to the time when we return to Congressman Brown.

Mr. **Brown**. Thank you very much.

Fortunately, there will be an opportunity to explore the fascinating issues further in smaller groups this afternoon and tomorrow. I am really looking forward to the results of some of these discussions.

Before we break for lunch, Dr. Ostenso has a logistic announcement.

Dr. **Ostenso**. Thank you, Mr. Chairman.

Dr. **Ostenso**. Thank you, Mr. Chairman. There is a change in room assignments for two of the discussion groups this afternoon; for

Group No. 1, elementary-secondary education, the room number has been changed to 2218. Group No. 3, special education, will meet in room 2325.

Thank you, Mr. Chairman.

Mr. **Brown**. Thank you.

At this time we will break for lunch. Lunch will be downstairs in this building in B–338. It is easy to find. I will look forward to seeing you there.

Thank you very much.

[Following a brief recess, Representative George E. Brown, Jr., chairman of the Subcommittee on Science, Research and Technology presented the following remarks at the seminar luncheon:]

Mr. **Brown**. May I have your attention for just a brief period of time. You can continue eating. See if you can eat silently. That's always a challenge!

I, unfortunately, have a commitment to attend a meeting of the Technology Assessment Board and I will have to leave shortly. It was my intention to make a fairly brief after-lunch speech to welcome you here and to indicate some views about the importance of the proceedings that we are involved in. I think that all of this goes without saying after the very stimulating and challenging morning session that we had.

I do want to, very briefly, tell each of you how much I appreciate your taking this time out of, I am sure, a very crowded schedule, to be here to help us in the Congress to appreciate the complexities of this very important problem of the impacts of converging technologies in computers and communications on the field of education, very broadly conceived. As I listened to the speakers this morning, I am sure that they all have a broad concept of an educational community in which the schools play the larger part, but, by no means, the exclusive part, as we move into a postindustrial society. Congress is just beginning to wake up to the importance of this.

We have here with us today some of the Congressmen who will be introduced to you after lunch. You will then not have to eat silently to listen to them. Senator Schmitt is here, from the Senate side. He has played a very key role in a number of important areas involving technology, including this one.

Congressman Van Deerlin, chairman of the Communications Subcommittee, is also here. He is trying to grapple with the policy problems that are involved in the regulation of the communications industry. He might tell you how difficult the policy issues are in that area.

There are other members here. I haven't had a chance to see exactly who is here, but they will all be introduced to you after lunch.

The point that I am trying to make is that we are beginning to realize that we face a technological explosion which will have impacts in a number of vital policy areas. They were just brought up and just touched on this morning. They are issues such as privacy and democratization of this technology, its effectiveness, of how various parts of the spectrum of technology will be divided between the public and private sectors, or various parts of the private sector. These are issues which we do not have answers to. We are hopeful, not that we will get the answers from all of you, but that you will help us to define the questions and indicate some possible options that we may consider.

As far as the work that is going on here, any Member of the Congress involved will tell you that it is an ongoing process. It will take considerable time. Lionel Van Deerlin has been involved for several years trying to come up with satisfactory solutions to rewriting the Communications Act of 1934, which was written before the satellites and before most of the technologies that it purports to regulate were in existence.

In my own subcommittee, where we deal with esoteric things like the space program and all the fallout from that, and energy, research, and development, and a number of other things—I can assure you that information and its impact on society is moving to the top of our priority list. We will be involved in it for years to come. As a matter of fact, the meeting that I am going to, the Technology Assessment Board, has several major projects involved in trying to assess the impacts of just small portions of this—electronic mail, for example, or computerized criminal systems. They expect to have, later in the year, some preliminary reports in these areas which will feed into the process and help us to evaluate the policy options.

So, this is the challenge that we have to try to put this tremendously, rapidly expanding, complex field into some perspective that will allow us to grapple with it in a coherent way within institutional systems which are not used to grappling with things in a coherent way. They prefer to grapple with them piecemeal and put them off as long as possible. That is the kind of situation we are in. We want you to share some of the sense that we have of its importance and to contribute to the solutions.

I want to welcome you here in this challenging task and to again express my appreciation and my hope that you will feel that your activities over these next 2 days will have been as worthwhile as I already feel that they have been.

Thank you very much.

[Whereupon, at 1:07 p.m., the subcommittee adjourned, to reconvene on Thursday, April 3, at 9 a.m. in room 345, Cannon House Office Building].

INFORMATION TECHNOLOGY IN EDUCATION

THURSDAY, APRIL 3, 1980

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY; AND THE COMMITTEE ON EDUCATION AND LABOR, SUBCOMMITTEE ON SELECT EDUCATION,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9 a.m., in room 345, Cannon House Office Building, Hon. George E. Brown, Jr., chairman of the Subcommittee on Science, Research and Technology, presiding.

Mr. BROWN. The subcommittees will come to order, and this little meeting will come to order.

We are going to proceed this morning for the first hour and a half with a couple of presentations, and I hope a little more adequate time for questions and answers after the presentations, and then we will break up into our smaller discussion groups. At about 10:30, we will have to vacate this room temporarily.

I want to welcome all of you again. I thought we might have lost a lot of you overnight. Washington is very easy to get lost in, but I see most of us are here, and I hope the day will be another productive day.

Let me make again the announcement this morning that we have an interpreter for those who may have hearing handicaps, and if there are such, we would invite them to come down to the front of the room where it might be a little easier for them to understand the proceedings, and if we don't have anyone, why, possibly we won't need to have the services of the interpreter. I am not sure.

Our first speaker this morning is Dr. Charles Mosmann, who is associate vice president for academic resource planning at California State University at Fullerton. He has previously been associated with the University of California at Irvine and has a broad background in computing and related problems which I won't elaborate on.

I will merely note that Dr. Mosmann apparently took his doctorate in philosophy—I am not sure, but he might be able to clarify that. This is a welcome change because most of the people I run into in this field are physicists or computer scientists or electrical engineers, and I have always felt we should have an injection of philosophy into this because it has important contributions to make.

In any event, I am looking forward to hearing from Dr. Mosmann, and we welcome him here this morning.

STATEMENT OF DR. CHARLES MOSMANN, ASSOCIATE VICE PRESIDENT, ACADEMIC RESOURCE PLANNING, CALIFORNIA STATE UNIVERSITY, FULLERTON

Dr. MOSMANN. Thank you for those words of introduction, Mr. Chairman.

Perhaps I should explain, I got my doctorate in philosophy. I had difficulty finding employment as a philosopher. A friend said he thought I could fake it as a programmer for 6 months because a doctorate in philosophy would enable me to fake almost anything for half a year. That was 20 years ago.

Mr. BROWN. Even in an earlier generation, about 40 years ago at UCLA, all the philosophy fakes would have to have had a background in mathematics or physics, I assume, because that would make them employable.

Dr. MOSMANN. I have been asked to talk to you this morning about our capabilities for evaluating new educational technologies and about the need for information on the part of individuals and institutions who need to make such evaluations.

My remarks will cover three points in the rough—and sometimes muddy—terrain of educational evaluation. First let me explain, I will restrict myself to those aspects of evaluation and those uses of instructional technology with which I am most familiar, and make no effort to present an overview of the entire field. I have worked in the use of computers in instruction and have been concerned with evaluating such use in higher education. That is what I am going to talk about.

My three points:

First, I should like to remind you of some of the reasons why the use of computers in instruction is complex and how this makes questions of evaluation difficult.

Second, I want to tell you what parts of the evaluation question, again regarding the use of computers in education, can and must be answered.

Third and finally, I will suggest how we might obtain better answers to those questions and how we might get more mileage out of the answers we do have.

Why the question is difficult: Educators and educational administrators have to make decisions about how they are going to use computers in the future, at least when they make their budgets. In order to do so, they would like to know how computers have affected education in the past and how they might affect it in the future.

The difficulty of finding straightforward advice on these questions lies basically in this fact: It seems to me in education—as in almost every other human activity to which they have been applied—computers have had as strong an influence on the content as on the method of the activity.

The computer comes in the door in the guise of a sort of intellectual steam engine, and we are inclined to view automation in the model of industrialization, to do work formely done by other means, but to do it faster, cheaper, or better in some other way. But it tends to have a different sort of impact, changing the nature and direction of what people do. I suggest that it is really more like a telescope than a steam engine. It changes human vision and thus imagination and thus ultimately human goals.

Computers in education have made our lives more difficult and not easier, as we were promised. The computer has not brought us closer to our goals, but has helped us to see further and thus to advance our goals, so that we find we have even further to go. Have computers helped us to achieve our educational goals? I think the answer is "No." But at the same time, they have made the question irrelevant.

In education, many early projections of the impact of computers saw the computer as a machine to replace human labor. The computer was to become the ultimate "teaching machine," doing at least part of the job previously performed by human teachers and providing a new medium of instruction in traditional subjects. The evidence, however, now indicates that—particularly in formal education—this kind of computing has played only a minor role.

Instead of being a passive machine for delivering information, the computer has provided a means for giving students a much greater insight into the world in which they live. Instead of replacing teachers, it has given teachers the means to provide a richer and more valuable education for students.

Of the greatest importance in the expanding use of computers in education has been the need and the opportunity to teach students how to use the computer in the activities they plan to pursue after leaving school. The computer has assumed an important function in the contemporary practice of business, industry, science, and scholarship. Its impact on the professions and the arts is growing. Almost no student can expect to remain untouched by this tool of almost universal applicability. So by changing the world of work, the computer imposes an additional burden on education: Prepare students to assume jobs where they will use the computer as a partner.

Thus, large numbers of students now use computers to do things that would have been meaningless a generation ago—they learn techniques of problem solving that rely on computers and they exercise this skill in projects that expand their knowledge both of information-processing skills and the subject matter to which it is applied.

In the social sciences, the computer has become a subject of instruction in another sense. The societal impact of this technology presents an urgent need for study and for control. In a democratic society, it is imperative that we have citizens who are informed about the nature of computers, how they are applied, and what the advantages and dangers of such application are likely to be. Some schools have recognized their obligation to review with students the social issues that the computer and its allied technologies have introduced, issues of which the rights of privacy and the impact of automation on employment are the best known.

As a consequence of these factors, schools and colleges find themselves pressed for expanding the curriculum by students—many of whom expect schools to provide them with access to computing and instruction in computer-related subjects—by the market for graduates—for employers are coming to expect applicants to have some basic computer literacy before they arrive on the job—and by the general needs of our society at large.

In the environment I have attempted to draw, it is clearly impossible to assess the value of computers in instruction in any absolute way. Things are changing and growing too rapidly to make that possible. My second point, then, had to do with questions that we can answer in the face of this situation.

We need to ask questions and come up with some sort of practical answers or else we would not be able to proceed with the educational process at all. Institutions need answers to these questions before they can make critically important decisions. I suggest five particularly important questions. The most evident—maybe perhaps because it affects budgets and therefore attracts attention first—is how much computing do students need?

A second important question is what kinds of computing do schools need? Because all computing is not alike. Some kinds are more useful for students, are more attractive and easier for them to use, and are better suited to the educational environment.

Third, since usage patterns diverge widely, how do you encourage students and teachers to make productive use of the resource, once it is provided? And perhaps most puzzling of all, how do you tell the difference between productive use and its opposite?

And then, finally, the most fundamental question, how does an educational institution go about answering these questions on its own, for the questions must have at least tentative answers in order for an institution to fit computing into its own institutional priorities.

A few years ago, with the support of the National Science Foundation, I set about trying to formulate some answers to these questions as they are asked in the context of higher education. The result of the study was a little handbook called "Evaluating Instructional Computing: Measuring Needs and Resources for Computing in Higher Education." It did not provide any ultimate answers, but it indicated some directions and warned of some dangers and a few institutions have found it helpful.

I had, in fact, set out to do something rather more ambitious than this. I had hoped to assemble facts and arguments to support some fairly straightforward advice and precise recommendations of what we must do. But there are just no authoritative pronouncements that can fairly be made about what the computing students should have—in part because of the reasons I outlined in the first part of my talk, and in part because institutions differ in their missions and aspirations.

One of the basic conclusions of my study and thus one of the premises of my handbook was that no universal answers are in fact now possible, but that each institution must work out its own decisions, based on its own priorities, the goals it puts forth for its students, the abilities of its faculty, what its community thinks are the priority and value of computing.

In attempting to provide help for institutional decisionmakers and planners in defining appropriate levels of computing support, my study suggests several alternative techniques. In particular, it stressed the value and importance of better measures of the quantity and quality of computing provided teachers and students to use. An administrator or a committee faced with the question of whether to expand or contract the computing resource should have more information about what students and teachers are doing than most institutions can now provide. Such data need to be more detailed than just "how much" computing is used. Questions of quality are of great importance, since they determine how effectively the computing is likely to be used.

In the absence of other criteria, many institutions find that the performance of peers is a valuable input. Techniques of cross-institutional comparison are also possible.

Institutions also need means of assembling consensus on what their present and future needs are. Of particular interest are survey instruments that ask faculty and other constituencies what levels of computer sophistication are appropriate to students at different levels and in different disciplines. Not many teachers can tell you what resources students need, but they should be able to tell you what students should be able to do. Ask the faculty, by all means. But also consider asking the alumni, and the students at higher levels; graduate admissions offices, employers in the community.

Techniques like this help to focus the decisionmaking process within an institution, providing more information and encouraging rational analysis in terms of institutional goals and objectives.

Still, the ultimate help in deciding where computing belongs in the priorities of education would be some hard data on what its impact has been on those being educated. And this brings me to my third point.

Over the past decades, we have had institutions where students have had access to liberal amounts of computing and others where computing is scarce and hard to use. We have seen students absorb thousands of hours of computing, and other students, in the same disciplines and working toward the same degrees, who have used none. What measurable difference can be discerned between these groups of schools, these groups of students? Does the use of computers in instruction make any difference? If so, what is it?

Without some evidence on these questions, it is certainly difficult to justify quantitative decisions about the amount and kind of computing that will be provided for students. Is 20 terminal hours per year enough exposure for the average student? How much better would a student's education be if that number were doubled? How would it be affected if it were halved?

The data to answer these question do not presently exist, but a sufficiently careful and detailed effort might bring them into being. The design and implementation of a project to collect this information is certainly no trivial undertaking. It will require examining a range of institutions of different quality aspirations. It will call for surveys and longitudinal studies of both institutions and students.

Still, while we are waiting for this major study, valuable information can be gathered from other briefer reports. Most of the data we have on computer use in education are based on computer center records regarding how many of the resources different groups use. Very little effort has been made to ask the faculty what their students are doing and why. Almost no systematic investigation has been made to find out what students really do in the hours they spend in front of computer terminals. Only the students have a large share of the most valuable information we want. It is hard to get good and reliable information from students, but if we learn to ask the right questions, they will tell us what we want to know. I should like to see many more studies that help us understand what the expectations of instructors are when they assign computer-related work and how they evaluate performance. I think we particularly need more research to help us understand what is going on, what kind of education is taking place, during the hours a student spends sitting before a computer terminal.

My final suggestion is not a request for more data, but for better use of the data we have—limited and inconclusive as it may be. It focuses not on the information needed to evaluate, but on the evaluator. A recent study by John Hamblen of the University of Missouri indicates that nearly 1,000 colleges and universities in America have no access to computing to offer their students. These institutions enroll over 1 million students. Students who terminate their education at the high school level have even a lesser opportunity; even though a growing number of high schools are acquiring computers, the percentage of their students who are exposed to them is very small. I should, therefore, like to suggest that the issue of evaluation is important only after the decisionmakers in education decide that the questions of evaluation are worth asking. Far too many of our teachers and administrators just do not care or—and this comes to the same thing—claim they do not have the skill, they lack the time needed, they cannot afford the cost.

Although we may not all agree on the exact nature of the computer's role in education, all of us who have examined the case closely agree that computers as such do have a role and that it is a role of some importance.

Students learn from teachers, and teachers learn from professors of education. Before students can learn from computers, the entire structure of professional education must become aware that computers exist and that they are relevant to educational concerns in a very broad context. Information technology must be seen as an opportunity for improvement, and not a threat. More important, it must be seen as important across the spectrum of education and not a specialty only for mentally gifted minors with a talent for mathematics. We must find better ways of reaching those educators who have made up their minds before the evaluation questions are asked.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Mosmann follows:]

THE EVALUATION OF INFORMATION TECHNOLOGY IN EDUCATION

Charles Mosmann
Associate Vice President
California State University, Fullerton

A report prepared for the April 3 hearings of the U.S. House of Representatives Committee on Science and Technology (Science, Research, and Technology Subcommittee and Select Education Subcommittee), as part of hearings and workshop on information technology in education.

I have been asked to talk to you this morning about our capabilities for evaluating new educational technologies and about the need for information on the part of individuals and institutions who need to make such evaluations.

My remarks will cover three points in the rough (and sometimes muddy) terrain of educational evaluation. I shall restrict myself to those aspects of evaluation and those uses of instructional technology with which I am most familiar, and make effort to present an overview of the entire field. I have worked in the use of computers in instruction and have been concerned with evaluating such use in higher education.

First, I should like to remind you of some of the reasons why the use of computers in instruction is complex and how this makes questions of evaluation difficult.

Second, I want to tell you what parts of the evaluation question, again regarding the use of computers in education, can and must be answered.

Third and finally, I will suggest how we might obtain better answers to those questions and how we might get more mileage out of the answers we do have.

I. Computers and the goals of education

Educators and educational administrators have to make decisions about how they are going to use computers in the future. In order to do so, they would like to know how computers have affected education in the past and how they might affect it in the future. The difficulty of finding straightforward advice on these questions lies basically in this fact: In education (as in almost every other human activity to which they have been applied) computers have had as strong an influence on the content as on the method of the activity.

The computer comes in the door in the guise of a sort of intellectual steam engine--to do work formerly done by other means, but to do it faster, cheaper, is better in some other way. But it tends to have a different sort of impact, changing the nature and direction of what people do. I suggest that it is really more like a telescope than an engine. It changes human vision and thus imagination and thus goals.

Computers in education have made our lives more difficult and not easier, as we were promised. The computer has not brought us closer to our goals, but has helped us to see further and thus to advance our goals, so that we find we have even further to go. Have computers helped us achieve our educational goals? I think the answer is, no. But at the same time, they have made the question irrelevant.

In education, many early projections of the impact of computers saw the computer as a machine to replace human labor. The computer was to become the ultimate "teaching machine," doing at least part of the job previously performed by human teachers and providing a new medium of instruction in traditional subjects. The evidence, however, now indicates that (particularly in formal education) this kind of computing has played only a minor role.

Instead of being a passive machine for delivering information, the computer has provided a means for giving students a much greater insight into the world in which they live. Instead of replacing teachers, it has given teachers the means to provide a richer and more valuable education for students. Although this has been true to some extent in all disciplines and subjects, the application has certainly been more widespread in engineering and the sciences than in less quantitative disciplines.

Of the greatest importance in the expanding use of computers in education has been the need (and the opportunity) to teach students how to use the computer in the activities they plan to pursue after leaving school. The computer has assumed an important function in the contemporary practice of business, industry, science, and scholarship. Its impact on the professions and the arts is growing. Almost no student can expect to remain untouched by this tool of almost universal applicability. So by changing the world of work, the computer imposes an additional burden on education: prepare students to assume jobs where they will use the computer as a partner.

Thus large numbers of students use computers to do things that would have been meaningless a generation ago--they learn techniques of problem solving that rely on computers and they exercise this skill in projects that expand their knowledge both of information processing skills and the subject matter to which it is applied. It is a truism that undergraduate students in many disciplines now do projects as a matter of course that would have been suitable subjects for doctoral dissertations twenty-five years ago.

In the social sciences, the computer has become a subject of instruction in another sense. The societal impact of this techology presents an urgent need for study and for control. In a democratic society, it is imperative that we have citizens who are informed about the nature of computers, how they are applied, and what the advantages (and dangers) of such application are likely to be. Some schools have recognized their obligation to review with students the social issues that the computer and its allied technologies have introduced, issues of which the rights of privacy and the impact of automation on employment are the best known.

As a consequence of these factors, schools and colleges find themselves pressed for expanding the curriculum by students (many of whom expect schools to provide them with access to computing and instruction in computer-related subjects), by the market for graduates, (for employers are coming to expect applicants to have some basic computer literacy before they arrive on the job), and by the general needs of our society at large.

2. Evaluating needs and resources

In the environment I have attempted to draw, it is clearly impossible to assess the value of computers in instruction in any absolute way. Things are changing and growing too rapidly to make that possible. My second point has to do with questions that we can answer in the face of this situation.

We need to ask questions and come up with some sort of practical answers or else would not be able to proceed with the educational process at all. Institutions need answers to these questions before they can make critically important decisions. I suggest five particularly important questions. The most evident (perhaps because it affects budgets and therefore attracts attention first) is how much computing do students need. A second important question is what kinds of computing do schools need. Because all computing is not alike. Some kinds are more useful for students, are more attractive and easier for them to use, and are better suited to the educational environment. Third, since usage patterns diverge widely, how do you encourage students and teachers to make productive use of the resource, once it is provided? And, perhaps most puzzling of all, how do you tell the difference between productive use and its opposite? And then finally, the most fundamental question, how does an educational institution go about answering these questions on its own; for the questions must have at least tentative answers in order for an institution to fit computing into its own institutional priorities.

A few years ago, with the support of the National Science Foundation,' I set about trying to formulate some answers to these questions as they are asked in the context of higher education. The result of the study was a little handbook called "Evaluating Instructional Computing: Measuring Needs and Resources for Computing in Higher Education."[1] It did not provide any ultimate answers but it indicated some directions and warned of some dangers and a few institutions have found it helpful.

I had in fact set out to do something rather more ambitious than this. I had hoped to assemble facts and arguments to support some fairly straightforward advice and precise recommendations. But there just are no authoritative pronouncements that can fairly be made about the computing students should have: in part because of the reasons I outlined in the first part of my talk. And in part because institutions differ in their missions and aspirations.

One of the basic conclusions of my study and thus one of the premises of my handbook was that no universal answers are now possible, but that each institution must work out its own decisions, based on its own priorities, the goals it puts forth for its students, the abilities of its faculty, what its community thinks are the priority and value of computing.

In attempting to provide help for institutional decision makers and planners in defining appropriate levels of computing support, my study suggests several alternative techniques. In particular, it stressed the value and importance of better measures of the quantity and quality of computing providing teachers and students to use. An administrator or a committee faced with the question of whether to expand or contract the computing resource should have more information about what students and teachers are doing than most institutions can now provide. Such data need to be more detailed than just "how much" computing is used. Questions of quality are of great importance, since they determine how effectively the computing is likely to be used. Range of hardware and software available is of course a measure of quality; but so are convenience, accessibility, availability of clear documentation and helpful human guidance, and simplicity of access for both teachers and students.

In the absence of other criteria, many institutions find that the performance of peers is a valuable input. Techniques of cross-instituional comparison are also possible. Until we have clearly comparable measures, the techniques will remain somewhat limited. Still, some comparisons are possible, if institutions will learn to use the data that exist.

Institutions also need means of assembling consensus on what their present and future needs are. Of particular interest are survey instruments that ask faculty (and other constituencies) what levels of computer sophistication are appropriate to students at different levels and in different disciplines. Not many teachers can tell you what resources students need; but they should be able to tell you what students should be able to do. Ask the faculty, by all means. But also consider asking the alumni, and the students at higher levels; graduate admissions offices; employers in the community.

Techniques like this help to focus the decision-making process within an institution, providing more information and encouraging rational analysis in terms of institutional goals and objectives.

3. Evaluation and the evaluators

Still, the ultimate help in deciding where computing belongs in the priorities of education would be some hard data on what its impact has been on those being educated. And this brings me to my third point.

Over the past decades, we have had institutions where students have had access to liberal amounts of computing and others where computing is scarce and hard to use. We have seen students absorb thousands of hours of computing and other students, in the same discipline and working toward the same degrees, who have used none. What measurable differences can be discerned between these groups of schools; these groups of students? Does the use of computers in instruction make any difference? If so, what is it?

Without some evidence on these questions, it is certainly difficult to justify quantitative decisions about the amount and kind of computing that will be provided for students. Is 20 terminal hours per year enough exposure for the average student? How much better would a student's education be if that number were doubled? How would it be affected if it were halved? These questions can only be answered on the basis of empirical evidence of the impact of computers on students.

The data to answer these questions do not presently exist, but a sufficiently careful and detailed effort might bring them into being. The design and implementation of a project to collect this information is certainly no trivial undertaking. It will require examining a range of institutions of different quality aspirations. It will call for surveys and longitudinal studies of both institutions and students. It may require that some talented and imaginative people postpone their efforts to improve education so that they can devote their talents to measuring education.

Still, while we are waiting for this major study, valuable information can be gathered from other, briefer efforts. Most of the data we have on computer use in education are based on computer center records regarding how many of the resources different groups of students use. Very little effort has been made to ask the faculty what their students are doing and why. Almost no systematic investigation has been made to find out what students really do in the hours they spend in front of computer terminals. Only the students have a large share of the most valuable information we want. It is hard to get good and reliable information from students, but if we learn to ask the right questions, they will tell us what we want to know. I should like to see many more studies that help us understand what the expectations of instructors are when they assign computer-related work and how they evaluate performance. I think we particularly used more research to help us understand what is going on, what kind of education is taking place, during the hours a student spends sitting before a computer terminal.

My final suggestion is not a request for more data but for better use of the data we have--limited and inconclusive as it may be. It focuses not on the information needed to evaluate, but on the evaluator.

A recent study by John Hamblen of the University of Missouri[2] indicates that nearly a thousand colleges and universities in America have no access to computing to offer their students. These institutions enroll over a million students. Students who terminate their education at the high school level have even a lesser opportunity; even though a growing number of high schools are acquiring computers, the percentage of their students who are exposed to them is very small.

I should, therefore, like to suggest that the issue of evaluation is important only after the decision-makers in education decide that the questions of evaluation are worth asking. Far too many of our teachers and administrators just do not care or (and this comes to the same thing) claim they do not have the skill, they lack the time needed, they cannot afford the cost.

Although we may also agree on the exact nature of the computer's role in education, all of us who have examined the case closely agree that computers do have such a role and that it is a role of some importance.

Students learn from teachers and teachers learn from professors of education. Before students can learn from computers, the entire structure of professional education must become aware that computers exist and that they are relevant to educational concerns in a very broad context. Information technology must be seen as an opportunity for improvement, and not a threat. More important, it must be seen as important across the spectrum of education and not a specialty only for mentally gifted minors with a talent for mathematics. We must find better ways of reaching those educators who have made up their minds before the evaluation questions are asked.

Quality computing is unquestionably of value in promoting the overall goals of an educational institution. It improves education, providing students with knowledge and insight that will be of value to them in several ways in their later lives. It helps them find jobs or get into graduate schools; it improves their insight into many subjects; it makes their work easier and more comprehensible; it promotes their understanding of the world in which they live. It is in pursuit of these objectives that the needs of students for computing must be defined and defended and that the quality and quantity of computing supplied for them to use must be improved.

Notes

[1] Mosmann, C. Evaluating Instructional Computing: In measuring needs and resources for computing in higher education. University of California, Irvine, 1976 and EDUCOM, 1977.

[2] Hamblen, J. and Baird, T., Fourth inventory, computers in higher education. 1976-77. Princeton: EDUCOM, 1979.

Mr. Brown. Thank you very much, Dr. Mosmann.

We will go to our second speaker before we have questions, and he is Mr. Ernest J. Anastasio, assistant vice president for research and development administration, with the Educational Testing Service in Princeton, N.J., and by background, a research psychologist.

I won't belabor some of the points that have put the Educational Testing Service into the news lately, and if any of those questions come up later, you can answer those for us.

We welcome you this morning, and look forward to your presentation.

STATEMENT OF ERNEST J. ANASTASIO, ASSISTANT VICE PRESIDENT FOR RESEARCH AND DEVELOPMENT ADMINISTRATION, EDUCATIONAL TESTING SERVICE

Mr. Anastasio. Thank you, Mr. Brown. I am pleased to have been invited to this hearing to submit information that I hope will be helpful to your committee in its important work.

As an organization dedicated to the improvement of education, Educational Testing Service (ETS) is strongly committed to the evaluation of educational innovations, and in particular technology-based innovations. Educational evaluation is the best source of objective information available to policymakers to assess the effects of new educational programs and, for that reason, it is important that evaluation be a part of every innovative effort.

In my comments this morning I will view the topic of evaluating information technology in education from a broad perspective, with particular reference to what I consider to be the fundamental set of issues that must be addressed in evaluating any instructional technology.

Although the "theory" of educational evaluation is applicable across different kinds of programs, there are some unique characteristics in the evaluation of technology-based innovations. For example, it is important to distinguish between the use of technology to improve access to educational instruction by delivering materials already available through other mechanisms (an example would be the use of satellite transmission of existing TV or radio instruction to remote locations in Alaska and the Appalachians) and the use of technology to augment and enhance existing instructional offerings. In the first case, the evaluation is primarily concerned with problems of implementing the innovative system and, if successfully implemented, questions of the extent to which the intended recipients make use of the instruction provided. In the example, the contest is between instruction via satellite and delivery of no supplemental instruction at all. Because of the nature of the comparison, technology is likely to be an easy winner in this case.

However, the largest potential impact of technology in education is in supplementing and enhancing existing instruction. This makes evaluation of the innovation far more difficult and demands that the evaluator make a systematic attempt to answer the following questions:

1. How did the innovation work—in terms of performance quality, reliability and flexibility?

2. What were the costs—in dollars, in personnel adjustment and in extra support and resources?

3. What were the effects—the intended effects on learning as well as the unexpected outcomes?

4. How was the innovation accepted—that is, for any implementation, how did the stakeholders, for example, students, teachers, administrators, and parents—react?

Other questions may be addressed in an evaluation, but these four are fundamental in assessing any proposed change in educational practice. They are fundamental because they reflect basic issues. Answering each of these questions requires that we state its context, and in the process, clarify what we mean by the question.

1. How did it work? Here we confront the "actual versus potential" dichotomy. Most technologies are evolving. It is not possible to evaluate the "potential" of a technology, except by expert judgment on actual performance. If we wish to gather hard data, these must be based on a current prototype. If preliminary evaluation reveals shortcomings, the developers can always announce another version, say a "Mark 2," designed to overcome the problems which the evaluation revealed in "Mark 1," and they can have "Mark 2" on the market soon after the analysis of "Mark 1" is completed. If the evaluator tries to be responsive by changing the evaluation to include "Mark 2," the developer can produce "Mark 3." When technology is not yet stabilized, the only way to answer the question "How did it work?" is to take a snapshot at a particular juncture, document it thoroughly, and use the information to improve the precision of expert judgment concerning future modifications.

For example, evaluation might indicate that a 5-second wait for feedback after multiple-choice response led to loss of interest among students. The developers might then announce a modification, capable of delivering feedback in 1 second, but limited only to yes/no responses. The data gathered on the original system cannot speak to the latency delay/response format tradeoff. In this sense, the "potential" of an evolving system can never be evaluated. Yet evaluations of limiting cases can be performed, and can influence expert judgments of potential. The question "How did it work?" can only be fully answered for a stable innovation.

No delivery system can be evaluated empirically without deliverables. Even though the delivery system is relatively stable, if it is flexible, the message can change. In evaluating systems designed to receive and deliver educational messages, the question "How did it work?" cannot be divorced from the particular curriculum implemented. And this is a point that I cannot stress enough: The curriculum delivered must be worth delivering. The temptation to exploit the capabilities of shiny new hardware almost invariably means that no "traditional" curriculum, or courseware to use the current vernacular, will be seen as sufficiently well-matched to the unique properties of the system to be readily adapted to the new technology. Thus developers embark on new curriculum development with an optimism uncontaminated by experience or by the knowledge that curriculum development takes years of trial, error, and revisions, and can consume vast amounts of resources, with a resulting product that is no better than that currently used in the schools. When such a home-brewed curriculum is delivered via the shiny new hardware, and evaluation shows it to work no better than does the traditional curriculum, the question of how well the medium could have worked if its message had been worth delivering remains unanswered, but the reaction of the education community is often to discard the system as having been proved to be ineffective. Language labs, programed texts, teaching machines, and individual filmstrip/cassette carrels are gathering dust in school storerooms all over the country, in testimony to industry's and educators' tendency to sell and buy thousand-dollar hardware associated with $1.98 courseware, and then to become disillusioned with the hardware.

The critical role of high-quality course material as an essential ingredient in any successful educational technology effort has been noted in countless projects. Reviews of numerous technology programs invariably make reference to the authoring process as the most uncertain and potentially disturbing aspect of the innovation. No matter how well designed and reliable the hardware, or how flexible and powerful the supporting software, the educational progress of students using any system will be limited by the nature of the curricular materials presented. Many project plans have substantially underestimated what is required to produce an effective curriculum, some by erring in the direction of excessive and premature systematization of materials lacking in adequate realization of the potentialities of the medium for delivery, and others by erring in the direction of excessive reliance upon highly inspired adjunctive exercises demonstrating the great versatility and creative potential of the medium, but inadequately supported by comprehensive, systematic coverage of curricular objectives. To my way of thinking, this issue is very real and at the heart of the problem; it must be recognized and dealt with if the delivery systems are to be given a fair trial and evaluation. Any major trial of a new delivery system should be preceded by carefully prescribed, small-scale, iterative experimentation, usually based on an already-proved curriculum approach, until the message being delivered is coherent and worth delivering. Only then is the question "How did it work?" worth answering.

At the risk of belaboring the issue, I would like to emphasize the point a final time by analogy. Suppose that the Air Force had under development a radically new design of fighter bombers and was preparing to test their effectiveness under combat conditions. We would expect them to insist upon experienced pilots and highly trained flight crews. And we would not regard it as a fair test of the new aircraft if the crews were selected on the basis of interest, ground artillery experience, knowledge of the combat terrain, or any other tangential criterion. Analogies are sometimes misleading, and I do not wish to push this one too far. The counterpart of an experienced flight crew, thoroughly skilled in coping with both a new craft and with combat conditions, would be extremely hard to find or assemble in the field of CAI. Most developers are to be commended for the ingenuity and perserverance with which they have faced the task of authoring for new media and for specific curricular problem areas, but the fact remains that in too many cases the skill, training, and experience needed for effective authoring has been grossly underestimated.

2. What were the costs? Any new delivery system requires new roles for teachers for effective use. In addition to training time, and the

costs—in terms of personnel and financial resources—of developing and delivering training material, it is necessary to consider opportunity costs throughout the teaching day. A system which requires active teacher intervention every few minutes severely constrains other teaching activities. On the other hand, a "turnkey" system, which operates completely independently of the teacher, may drive the teacher's pace and coverage, or lead to the inefficiency of two unintegrated treatments of the material. I will return later on to the issue of "teacher-proof" systems in my comments on acceptance of technological innovations.

When dealing with an evolving system, even direct monetary costs are difficult to track. It is clearly in the developer's interest to assign as many operational, implementation, and service costs as possible to the "development" category, thereby lowering the estimated cost of routine delivery of the developed system and courseware. If system and courseware development are allowed to proceed concurrently with evaluation field trials, it may be impossible to separate the costs. Thus, the researcher's desire to evaluate a stable treatment is not so much evidence of a lack of methodology to deal with dynamic phenomena, but an insistence that determining accurate operational cost is essential to informed decisionmaking. This position is related to the growing feeling that the most reasonable target for summative evaluation is a replication of the pilot system rather than the original, in conditions other than the developer's back yard. This is not to diminish the importance of formative evaluation during the development and pilot phases of a project.

3. What were the effects? This is the traditional question of educational evaluation. As decisionmakers become more sophisticated, and as evaluators learn to cut through some of their professional jargon, it becomes clear to all that this question, when worth asking, does not have a simple one-number answer. An increasing segment of the public is aware that the question is not, how much did students learn—raw grain—but how much more or less did they learn than would have been the case if they had not received this treatment? To answer this question always requires assumptions. If we can compare the students with a similar group under conditions of random assignment the assumptions are minimal—on the average, the control group will not differ systematically from the treatment group on any characteristic but the fact of receiving the treatment. If students and teachers are systematically selected or if they select themselves into the treatment, strong assumptions must be made to determine all the important ways in which they differ from individuals who did not receive the treatment. For example, people who watch opera on public television tend to have larger vocabularies. Very little, if any, of this difference is because watching TV opera builds vocabulary. Rather, both characteristics tend to be associated with higher education level. When self-selection occurs, one must use extreme caution to make sure that differences in the treatment and nontreatment group were not predictable before the treatment took place. There are statistical methods for attempting this correction, but they assume that all important preexisting differences have been accurately measured—an assumption which is never verifiable.

The public is becoming more aware that a system that gives positive results with one population in one setting may give quite different results with different groups in different settings. Valid evaluation should look at such interactions to attempt to set limits of generalization. The key factor, of course, is an experimental design that is appropriate to the situation. In its simplest form the design would include two comparable groups, one of which receives the innovation and one that does not. However, even this simple design is difficult to implement in practice. To the extent that the innovation is perceived as beneficial, it is possible that the group who is not receiving the innovations will find ways of supplementing their instruction. For example, if the two groups correspond to different classrooms, the teacher in the control classroom may supplement regular instruction by various means. The effect of such a comparison would be an underestimation of the real impact of the innovation.

The way to deal with problems such as this is by using designs that are robust to this problem. One such powerful design, made possible by the individualizing technologies such as CAI, is the delivery of different curriculum, say reading or mathematics, to randomly assigned students in the same classroom. Then the reading group becomes the control for mathematics, and vice versa. This design has been used to good effect by Patrick Suppes for precise within-classroom evaluation and is, in fact, an important element of the design being used by ETS in the NIE-sponsored evaluation of drill-and-practice CAI in Los Angeles. Another mechanism for dealing with the problem is to assess the types and amounts of instruction received by the different groups and incorporate that information in the analysis.

In short, to the extent that innovations are accepted or rejected because of their impact on achievement, it is important that such impact be accurately assessed. Underestimation or overestimation of the effects of an innovative program may lead decisionmakers to the wrong decision. Hence optimal experimental designs should be a high priority item in experimental evaluation.

4. How was the innovation accepted? No matter what the impact on achievement or other cognitive test scores, the evaluation of a technological innovation must ascertain the attitudes and reactions of students, teachers, administrators, and parents to its intrusion into their lives. Sometimes such information must be inferred from the observation of behavior, but sometimes it is more directly available in responses to tradeoff questions. For example, at the end of the PLATO elementary school demonstration, teachers were asked, "If you had the choice between a half-time aide and PLATO terminals in your classroom—approximately equivalent costs at that time—which would you choose?" A majority of intermediate mathematics teachers opted for PLATO but a majority of primary reading teachers chose an aide. This sort of evidence of degree of acceptance, in terms of tradeoffs, rather than of "Would you like it at no cost?" is necessary if decisions are to be made in the real world of scarce resources. Even if a system is designed for add-on use, rather than substitution for the teacher's time, its adoption will not be an add-on in these days of taxpayer discontent, but will replace something in the budget. To be accepted, it must be seen as more cost effective than something already in use.

Acceptance by teachers requires that the teacher be able to retain some professional autonomy over mode and timing of use, and instructional sequence for individual students. The system which is designed to be teacher proof, diagnosing, routing, prescribing, delivering instruction, and testing for mastery independent of the teacher, makes it impossible for the teacher to integrate the system with other classroom technologies. Just as seriously, such a system leaves no provision for human corrective action when a student gives a response that the system or curriculum designers did not foresee. In the absence of omniscient designers, such unpredicted behavior is likely to take place every time a child sits down at a preprogramed device. For these instances, teacher-proof systems very quickly become teacher-rejected systems. The answer to this problem is not to design increasingly complex teacher-proof systems, but to include the teacher in the feedback loop, making the technology a tool to be used by a trained expert, rather than a fast and colorful, but mute, simulated expert. Progress in artificial intelligence may someday make it necessary to revise this assessment, but for the foreseeable future, teacher resistance to closed systems which they cannot guide will be based on sound pedagogy, and not merely fear of being made obsolete.

It is becoming increasingly apparent that many evaluation findings could have been predicted simply by looking at the content of the treatment curriculum, the content of comparison curriculum, and the match between each and the content of the tests used. It is important that such tests cover not only the curriculum, but also include transfer items not covered by either the treatment or control curriculum, but reflecting possible positive or negative side effects. A curriculum which stressed problem solving exclusively might be found to have a negative effect on computation, but the evaluator would have to look to determine whether the innovation improved conceptual understanding or merely performance on computational tasks. Clearly the ultimate objective is the improvement of understanding but there can be an improvement of test performance without a concomitant increase in understanding. A case in point was found in the evaluation of CAI in Los Angeles cited earlier. Although test scores increased for children receiving CAI they tended to make the same sort of errors with the same frequency as children that did not receive CAI, suggesting that test taking skills, not understanding, were improved.

Gavriel Salomon has argued persuasively that new methods to measure the impact of new media on students' conceptions of and styles of working in a subject are a high priority need in evaluation of new educational technology. By observing student interactions with new technology during the important piloting phase, prior to formal summative evaluation, and by utilizing clinical interview methods, evaluators can generate hypotheses concerning novel outcomes, and develop instruments to assess them. As an obvious example, a system which allows a student to construct a response, rather than simply to select from among alternatives, may not be assessed effectively with multiple-choice tests. Deeper effects, for example, on the student's notion of the structure of a body of knowledge, will not be captured without major efforts to design measures which probe these less superficial structural understandings. This argument—that different media vary with respect to the kind of mental skills they activate, and for that reason also vary with respect to the kinds of achievement they produce—may prove to be the greatest challenge in evaluation of technological innovations, and may lead to different and more appropriate accountings of the unique educational outcomes that result from their implementation.

Before concluding I would like to make on final comment regarding the role of the teacher in effecting educational reform, and the implications for evaluation. There are no census figures to substantiate it, but the estimate is plausible: more programs intended to change classroom instruction were rained down on elementary and secondary schools in the past 20 years than during the entire history of public schooling. The nature of the desired change varied with the interests—vested and intellectual—of the reformers, and this diversity of ends was exceeded only by the varied means chosen to bring them about. The blueprints differed from one another on some critical aspects of affecting change. One of these aspects, the part the teacher plays in implementing proposed innovations, is especially relevant to the topic of evaluating instructional technology. Conceptions of the teacher's role in reshaping educational practices have ranged widely, from the view of teacher as obstacle to change, whose influence is best counteracted or neutralized, to one that solicits the active support of the teacher and, in fact, views teacher development as the predominant aim. In all cases, the presence of the teacher must be confronted by anyone seeking to alter school life.

Given the teacher's centrality in the classroom, it is surprising that decisions about implementation strategies have often been made with scant knowledge about the pedagogical values and constructs held by teachers. The question of the compatibility of a program's goals with those of the teacher's has seldom been raised. This curious lack of interest in the teacher's viewpoint, the "odd gap" often referred to in teacher research, is all the more remarkable if one considers the universal aim of many innovations, bent on no less than the improvement of all instruction efforts.

This problem, of course, is not unique to instructional technology and I do not mean to suggest that technology developers are more guilty than others engaged in instructional reform; however, it seems especially appropriate to raise the concern at this time as we consider strategies to meet the challenge of evaluating innovative technology programs.

In closing let me reiterate my firm conviction that quality evaluative data is critically important to decisionmakers—be they developers, potential consumers, funding agents, sponsors, or students—and that these data will only obtain from comprehensive examination of stable systems with carefully prescribed curriculum implemented in contexts which as nearly as possible reflect the realities and complexities of contemporary school settings.

Mr. **Brown**. The floor will be open for questions at this point, and as we did yesterday, I will ask the questioners to stand and to identify themselves in some appropriate way, possibly by a name even. We may proceed at this point.

Who wants to ask a question?

Mr. **Komoski**. I am Ken Komoski, EPIE Institute, New York City.

I wish the last point you made, Mr. Anastasio, were true universally in schools in this country. I wonder what you would feel about—how you would respond to—the reaction we find around the country that decisionmakers tend not to look at evaluative data. This was brought home to me very recently in a class I was giving at Columbia, just 2 weeks ago. We had representatives of the publishing industry who were from research departments who had in fact been doing iterative evaluation of their materials. One of the comments they made was that people in schools, decisionmakers, just do not pay much attention to the efforts that they are making in the publishing houses. A few publishing houses are now paying attention to the issue of evaluating their materials carefully. One of my students said: "What then do you believe is the critical variable regarding persuading people in schools to buy what it is you are selling?" It was a knee-jerk reaction: "Packaging."

Now, how do we get people to pay attention to the last point you made, which I sincerely wish were the case out there, but I don't, from my perspective, feel it really is, and we have a long way to go to get to it.

Mr. ANASTASIO. I wi[illegible] I had an answer. I think part of the problem rests with the evaluators who have been somewhat derelict, I think, in understanding and following through on their responsibilities to consumers.

Most evaluators are trained as research scientists. They have a tendency to talk to one another in terms that research scientists understand, and to respond to the kinds of professional rewards that exist in their field, rewards that grow out of academic traditions where one publishes in refereed journals and shares results with colleagues in professional assemblies. I think a large part of the problem is with the evaluators and the developers who have to learn to package their results in ways that will get the attention of the school boards, Members of Congress, and the like. Social scientists in the past few years have become much more sensitive to their obligation to couch and frame recommendations in terms that policy makers can comprehend and react to, and hopefully as we continue to change our behavior in those ways our packaging will rival in impact the packaging of developers.

Mr. BROWN. Next question.

Mr. KURLAND. Norman Kurland, New York State Education Department. Mr. Anastasio referred to language labs and other experiences that we've had with technology. We find in our State—I gather this is true in other States as well—that school districts are buying microcomputers at a very rapid clip, putting them into classrooms, and then we hear concerns about whether there will be enough courseware to make them really work. I wonder why you think, if you do, that the experience with this technology is going to be any different than with previous technologies, and what your advice would be to Congress, to the Federal Government, to those of us in the States, and others, to try to make sure this time that this turns out to be a really effective technology and not one that ends up on the shelves in the closet 5 years from now.

Mr. ANASTASIO. To be perfectly frank, I'm not confident that our experience with microcomputers is going to be very much different than with other technology, for the reasons I was commenting on in my remarks earlier.

I have seen some startling dramatic demonstrations with microcomputers, video disks, terminals of one kind or another, and combinations of audiovisual media. They are very compelling, highly entertaining, provocative, stimulating; and they have all the aspects that good TV entertainment should have, including some substance, I am sure.

My conviction, based on spending lots of hours in the classroom, especially elementary and secondary schools, is that bringing the microcomputer, or the language lab or whatever it is into the classroom is disruptive in positive ways, much as bringing a snake or a rabbit into the classroom can be disruptive, and it is on the basis of that experience that we say "this is what we need," it brings all of the elements together in appropriate ways and we contract to buy it, or rent it, or whatever we do. And that course material and the demonstrations serve them well for a week, a month—maybe even a semester or a year.

The problem then becomes the courseware problem that I alluded to before. There is no industry behind the scenes now generating the lessons, modules and courses to follow on from the demonstration materials, and because that industry is not there, we are let down after we have had our fill of the materials that came with the machine. That picture has not changed very much in recent years, and I don't accept at all the notion that teachers will generate the material. All of us have been educated and we have all used many text books in the course of our schooling, most of which were not very good. Some of us who were lucky had the privilege of using good text books in one course or another; some of us were even more lucky and had the good fortune of running into a master teacher. There are very few master teachers, and I'm positive there are very few people who have the ability to develop good course material, whether for micro, mini, or whatever. I think that is true now and will continue to be our experience.

Mr. BROWN. The gentleman right there.

FROM THE FLOOR. I'm from Rutgers University.

In your presentation, you indicated that we need more experimental designs, especially robust experimental designs, and you indicated that the power of an experimental design is that it enables us to determine whether the treatment has produced desired effects. That however does not answer the question of what caused the treatment to yield the desired effect. Will the treatment cause the effect in other settings and probably the most important of all, how worthy is it to achieve the effect, given the costs involved? That would sort of boil down to a major issue, I would think, if what I have said is true.

The issue is, can the evaluation provide a solid guide for the adoption of this technology, and if it can, what kind of evaluation can deal with all those questions?

Mr. ANASTASIO. I think your statement is essentially accurate. Evaluations can provide answers. I was arguing for as much control as possible on the part of the evaluators so the decisions can become clear. By way of example let me make reference to the evaluation that we conducted for the TICCIT project in the middle 1970's. There was a case where. with a lot of effort on the part of developers and evaluators to cooperate with one another and create an implementation of that system that was most sensible, we were able to determine that the particular instruction programs could produce a positive impact on student achievement.

In a nutshell, that project showed that students who went through the TICCIT program of instruction performed at higher levels than students who did not; however, the tradeoff, the cost of higher TICCIT performance was a substantial reduction in the number of students who completed the course versus the number who didn't. Only 16 percent of the TICCIT students finished the course to get credit versus 50 percent of the students from the classroom. That was the case in math. In the case of English, it was about 50 or 55 percent of the students finishing with TICCIT, and about 66 percent finishing in the traditional class.

The design was a good one. It was clear from the data that we could speak with great confidence about the positive impact of the TICCIT program. Then the question for the policymaker became—can we afford to invest in this product so that we can obtain a higher level of mastery but risk having it take longer?

Mr. Brown. Let me suggest that questioners use the floor mike so that everyone can hear you, if that is not too inconvenient.

Mr. Gillespie. Bob Gillespie, University of Washington.

I have a question for Dr. Mosmann. The questions on evaluation in higher education were very good. He also pointed out the difficulty of answering those. I wonder if he has any suggestion about incentives toward the answers—for instance, the coming financial crises might provide some incentive to answer those questions on evaluation, but I wonder if there are any other possibilities?

Dr. Mosmann. No; I think you have suggested the only answer that occurs to me, that the primary incentives to evaluation are budgetary. The financial pressures on education today require a more rational approach to the assessment of alternatives and the allocation of resources.

Mr. Brown. You, sir.

Mr. Wiesner. I am Peter Wiesner, Essex County College.

From the comments of Mr. Anastasio, it seems that instructional design is an integral part of evaluation, and that the evaluation of course work should begin at the very onset. Once materials have begun to be developed, they should be pilot tested and rigorously field tested before they are ever put out in the market.

My question is, if Government funds are to be spent for courseware for the schools, should we require that products undergo this process?

Mr. Anastasio. I would be leery of answering that yes or no. I have visions of mechanisms that could result that would be bulky and unnecessarily difficult to manage. On the other hand, I would be very much in favor of a better shake than now exists for the evaluation of materials.

As Ken pointed out earlier, most of the materials purchased in school systems are purchased as a result of the package, or probably the ability of a representative of the company to convince the school board that is where it should go. I would like to see us do better than that.

What I'm in favor of is that any project that the Government sponsors—and they've been very good about this—have associated with it the opportunity and provision for careful evaluation. The Los

Angeles study that NIE is sponsoring is now in its 5th year and it ends in September 1981. At that time we will have data on a number of elementary school children who, for a period of 4 years, have received exposure to regular drill and practice exercises. This is with a system that was complete when we started, with off-the-shelf hardware, and the design that I mentioned as being the most robust is what we are using. That will give us a good basis for any decision about the impact of those materials.

If Government-sponsored programs could be set up so that the provision for that kind of study is made, I would be happy to hear that.

Mr. **Brown**. The gentleman back there.

Mr. **Raucher**. Steve Raucher, Montgomery County Public Schools.

I agree very much with what Mr. Anastasio said; the problem that I sense is a Catch 22 situation, the half-life of the technology, which has been primarily led by the semiconductor industry, is something like 14 months. The requirements to perform careful curriculum development and evaluation exceed that.

Do you feel there is a way to bridge this dichotomy, for example, a required standardization of software technology from the technologist's side that would be required before any curriculum development could take place?

Mr. **Anastasio**. You make a very good point, and I would be very much in favor. As we move to higher level languages in computer systems there is more of a chance to get some standardization, and though it would be premature to impose on the industry those standards now, it would be very nice if we could move to that. Of course we have it in our TV industry, and we are moving to it in the tape industry, so maybe we can move to it with computer systems. Of course it is very much against any company's best interest to develop something to be used elsewhere, but I would like to say I hope it moves that way.

Mr. **Brown**. I think some of you might be familiar with the recent effort to impose standardization in the peripheral equipment to computers which raised a tremendous stink when this effort was made by the NBS, and it is a continuing policy problem which I am glad you are bringing up here. I would very much like to know what the proper way to do it is, because you are always accused of inhibiting competition when you impose standards, and you have to weigh both sides of the equation very carefully.

The gentleman over here.

Mr. **Levy**. Allan Levy from the University of Illinois.

I want to ask an auxiliary question to the matter of stability and evaluation. It is not only the nature of the technology that is changing but rather the evanescent nature of funding, whether the funding be from governmental, university, or commercial. It is usually short term and there is often a requirement to either evaluate or reapply for additional funding just about as the project begins. I wonder if there is a way to begin to approach continuity in curriculum development of educational innovation in the same way as there is continuity in the more traditional forms?

Mr. **Anastasio**. Another very good point.

The project I cited before is a study we are doing in Los Angeles, a 5-year longitudinal study, and it has taken the full time attention of an NIE program director to see that the budget remained intact for the past few years.

One of the problems that has plagued the project in the past is the one you referred to, funding for a year or two and then intense pressure to produce some results. And I guess the only solution I have is more stability in the funding of those programs. This would be one way out of the problem you mention.

Mr. **Brown**. The gentleman in the rear.

Mr. **Caravella**. Joe Caravella, National Council of Teachers of Mathematics.

In light of what we saw with the calculator entering the classroom through the consumer market and the calculator not gathering dust today, I have some concerns that the business community has now seen a method, a profitable method of entering the education business, in what we are seeing with the micros at this point. I think that is a direct parallel with the calculators.

I was very interested in hearing the comments of the representatives this morning on expanding the definitions of schools. Education does not only take place in the schools. In light of contemporary information technologies, all of them, not just the computers, all the various games and toys, and materials coming off the market that are dependent on a great deal more thinking by children in their very early years, could we expand some of our comments to integrated home-school educational experiences?

Mr. **Brown**. I think that would take a philosopher to answer.

Dr. **Mosmann**. I will see if I can muddy the question and Ernie can polish it off.

When Mr. Gillespie asked me a question earlier I paused as to whether I should move into another area. One of the reasons I think higher education ought to be more interested in these technologies is for just this reason. Competition from other forms of education may turn out to be more practical and even cheaper than formal higher education. It is very real; I don't suppose there are many people in the education field who realize this yet, but many of the forms of instruction that are now delivered by public supported schools and particularly in the higher level, can be provided and are being provided by other means, which turns out to be more economical for the student.

Mr. **Anastasio**. With programs like Sesame Street and The Electric Company we have seen examples where some portions of instruction were provided to kids via television, and in each of those programs I just cited, children can develop skills and at very low cost.

I think there will be more opportunity in the future for people to become responsible for their own education and that of their children. I am not sure I like it right now. What it may be leading to is a further split between the disadvantaged of our country and the less disadvantaged. We have the case in a lot of major metropolitan areas, where school boards are forced to make cuts in programs they offer, and the impact on the community is devastating in the sense that people who cannot afford to procure the services being cut do without them. Others who can afford it go outside to the private sector and are gaining that much more advantage or opportunity. I am also entirely confident that the private sector people who provide the services are being motivated by all the same things I would be motivated by if I were standing in front of a classroom. They might not be willing to take all of the care they ought to be taking in providing alternate forms of instruction. But we are clearly moving in that direction.

Dr. Mosmann. I just wanted to make another comment here. I would not question or downgrade the importance of the careful analysis such as ETS has been doing, like in Los Angeles, but a few of the comments have led me to remind you that we are also to focus our attention on the people who are making the decisions.

In the case of the marketing concept, the people who are making the decisions in the schools are using some kind of information. We must look at what their problems are and the way they make decisions. We must find ways to help them.

Insofar as it is not the educational establishment that makes decisions about what mode of instruction would be used, the student himself or herself will make it. The person who would like to speak French has an alternative of going to the community college or plugging into the TV set at home. That person is making an evaluative decision.

Mr. Greis. My name is Howard Greis; I am a lay member of the Massachusetts State Board of Education, and unfortunately I probably represent the type of ignorance that makes some of these decisions, and therefore you may be saying why is it that packaging sometimes makes a difference. and I sit here and I have sat through a number of these discussions, and unfortunately the jargon, the length of time it takes for studies and this class of things generally makes the great majority of the public wonder about the quality of the studies that come out. A good example of this is the business of mastery education. I have talked to a number of parents about that, and they say: "What, isn't that what we are always doing? Or at least, "Isn't that what we should have been doing?" You know, we ought to teach the person what we are trying to teach him; and if he does not learn it, we should give him some help in the classroom. This is typical. The same holds true recently of a whole series of reports which say that, in essence, the main thing that makes success in basics is successful time on task. So a parent says to me, "Well, practice makes perfect, doesn't it?" I think that part of the problem here is that the public is making a decision for you right now because they sense the microcomputer represents an ability to do a lot of these very simple-minded things, and when they hear about longitudinal studies, and all that sort of thing, they throw up their hands and say "more educational jargon."

We went from 3.7 to 7.5 percent of the gross national product, and they have not seen any significant difference. They say "Hey, what's happening here, it's costing money and we have no difference." So whether we like it or not, the microcomputer represents something new, some possible change in direction, and I think from my talking with people, whether you believe it or not, this is the primary motivating force behind all of this, and you're all going to be way behind the public unless we find some better way of approaching the whole issue. Thank you.

[Applause.]

Mr. Brown. I guess that is a rhetorical question, but it is a very important point that needs to be made over and over again. But it needs to be made in the most positive way, and that is that of expanding the horizon of educators rather than contracting their horizons. For example, if we are going to make the best use of this technology, and a lot of it is going to be done in the home, the office, or the community, maybe we ought to think about how to impact these factors so as to get the best educational product out of it rather than just letting it go by accident or by the pressures of the private sector to market it as effectively as possible.

The gentleman back there.

Mr. **Greenup.** William Greenup, U.S. Marine Corps, Education Center, Quantico, Va.

Dr. Mosmann, in your remarks this morning you mentioned several questions that need to be answered in institutions about computer-assisted education, including such things as how much computing does a student need, what kind of computing, what can the institution do to encourage students and teachers to make effective use of it, and then you asked how does an institution go about answering these questions on their own? I was wondering in this regard if you or Mr. Anastasio could recommend any useful models that exist that would enable institutions to identify potentially high payoff areas for computer-based instruction.

Mr. **Anastasio.** Well, I don't know how to answer your question; some of the most successful projects that exist now are the ones that deal with the development or refinement of basic skills or straight forward training situations as opposed to more advanced conceptual instruction.

Dr. **Mosmann.** I indicated in the beginning of my talk that I wrote a handbook where I put together the best I could find as to how to answer these questions.

Mr. **Brown.** Any additional questions?

The gentleman back here.

Voice From Floor. If I may ask an additional question to the Chair?

Mr. **Brown.** You may not get a good answer, but feel free.

Voice From Floor. In view of the recent comments about the potential of the delivery of educational services to the home via the new technological means, what do you think should be the role of Congress and the Federal Government in both facilitating development of this kind of service and assuring that as it develops, we will not be further disadvantaging those who have not benefited fully from our existing educational system? In other words, how can we try to prevent the gap between the educational haves and have-nots from widening as a result of these technologies?

Mr. **Brown.** Well, the role of the Congress in answering that question is not at all clear to the Congress. We need as much education as any other important community playing a role in this technological revolution. And of course that is part of our purpose here today. But we will approach this in several different ways. One, of course, is to try and bring about some structure of regulatory order as to the role of the various factors in the market place here; that includes the schools, the commercial media, other public organizations and so forth, which we have not done yet.

If we are going to address the fundamental problem that you raise of inequity in society and inequitable access to information resources which is merely another phase of the problem of inequitable access to all resources in society, that needs to be addressed through a range of initiatives, including the fundamental one of producing a more egalitarian society; in other words, making economic opportunity more available to everyone so that to the degree that individuals choose to do so they have the resources to take advantage of the information facilities that exist.

I am sure all of us are aware of the phenomenon that practically every family in this country has access to a television set. The economic inequalities do not seem to have precluded individuals even in the poorest strata from feeling that their lives would be incomplete without a television set of some sort. Hopefully we can continue along this path by making the demand for information resources and learning opportunities as attractive as with access to "All in the Family" or whatever else it is that they happen to be using their television for. That, of course, gets back to even more fundamental questions of how do you motivate people to want to acquire knowledge, information, learning, so that they may play the role they are potentially capable of in the society.

That question goes far beyond the question of this technology. I don't think that the course is going to be the Federal Government deciding that everybody should have a computer and subsidizing poor people to acquire computers. We have done similar things in limited cases; for example, we are spending a quarter of a billion dollars a year to make sure people don't freeze to death because of the high cost of heating oil, but I don't think we are going to put computers or learning technologies in that same category. I think we will have to address the more fundamental problem of inequality in society. That is about the best answer I can give to that very profound question.

Do you gentleman care to offer your own suggestions? [no response]

Mr. BROWN. This does bring us to the magic hour of 10:30, and the people who want to set this room up for lunch are eager to get into the room, so we will call a halt at this point to this phase of the seminar and we will proceed to our smaller group meetings.

AFTERNOON SESSION

RECOMMENDATIONS OF WORKSHOP DISCUSSION GROUPS

The subcommittees met, pursuant to notice, at 1:30 p.m., in room 345, Cannon House Office Building, Hon. George E. Brown, Jr., chairman of the Subcommittee on Science, Research and Technology, presiding.

Mr. BROWN. The subcommittees will come to order.

The waiters will come to order. Everybody else will come to order.

This afternoon we will have the opportunity—I will have the opportunity to learn what has developed out of our deliberations here and for that purpose we have the chairman of each of the six workshop discussion groups who will give us a brief, we trust about 10 minutes each, digest of the results of their workshop discussion. Then after each one, if we are rigorous, we may have about 5 minutes for questioning from the audience, and if we keep to that schedule we will be able to finish somewhere close to our programed 3:30 ending time.

After each of the discussion groups has made their reports, we will ask Bob Chartrand of the Congressional Research Service, who is our resident expert on information systems, to make a few summary remarks and that will conclude our seminar.

Now we will take the panel in order and our first will be the Elementary-secondary Education group which was chaired by Dr. George H. Litman, who is staff assistant for the Bureau of Computer-assisted Instruction at the Chicago Board of Education.

Dr. Litman, would you mind using the podium up here.

ELEMENTARY-SECONDARY EDUCATION: PRESENTED BY DR. GEORGE H. LITMAN, STAFF ASSISTANT, BUREAU OF COMPUTER-ASSISTED INSTRUCTION, CHICAGO BOARD OF EDUCATION

Dr. LITMAN. Thank you, Mr. Chairman.

The contributions of men and women who participated in the Elementary-Secondary Education Workshop yesterday and this morning were invaluable to me and made this presentation possible. I would like to take this opportunity to thank all of them for their dedication to the improvement of education. However, trying to summarize within 10 minutes the diverse opinions of the 33 different participants at the workshop requires a technology that has not yet been invented. Yet, I will attempt to do just that by summarizing the major concerns of the participants and then humbly suggesting some possible Federal action to mitigate those concerns.

The workshop on Elementary Secondary Education wants to make it clear that information technology in the public school sector falls into two major categories. That is, information technology plays two important roles in public education today.

On the one hand it is the object of instruction, and on the other it is the tool of instruction. These two roles are very distinct; they result from different needs, present different problems, and permit different solutions.

As the object of instruction, I refer to what is commonly called computer literacy and what was yesterday eloquently called computer comfortableness. The computer is an integral part of the American economic system. It runs the subways, keeps our bank accounts, sends us bills, and computes our paychecks. It is clear that every citizen should understand the general principles of information science. Computer education at the elementary and secondary levels is therefore desirable and feasible. However, the following concerns arise during the implementation of such a program.

First, there is a concern about the equality of opportunity. That is, how are we to expose students equally to such technology. This information and communications technology explosion has already and will continue to shatter the concept of the classroom as the center of learning experience. Learning experiences in the home, the library, the museum, and the shopping mall are not equally likely to happen to all children. Present financial and marketing resources of schools favor specific subpopulations.

Second, how are we to provide the necessary training and retraining of teachers of elementary and secondary schools to permit them to understand and use the new available technologies. This sudden explosion of learning technology has left the majority of teachers in the schools with little knowledge and/or experience with the new technologies. During the formal learning periods of the majority of teachers these modern information technologies did not exist and no effort has been made to bring this knowledge to them.

Third, how are we to provide the training and retraining necessary to permit enlightened decisionmaking by administrators and "paraeducators"—those people involved in education but not directly in schools, including members of this subcommittee. These educators, like teachers, are in desperate need of knowledge about the capabilities of the new information technologies, but unlike teachers, are not frequently involved in inservice or continuing education programs.

The second major role in education for technology is as a tool of instruction. As a tool of instruction, I refer to what is commonly called computer-assisted instruction or CAI. Whether viewed as a network with a large-scale computer system with large numbers of terminals or as individual microprocessors, the issues of concern were much more complex than they were for the first category. The four major concerns were:

1. Reducing the further separation and polarization of the population because of the new technology. This technology, in the form of the home or hobby computer, has already made a tremendous impact on the home and school market. However, this market generally represents the affluent, the "haves," the suburban school. It has not made an impact on the poor, the "have-nots," the city school. The result is that the benefits of CAI will not accrue to those who most desperately need them.

2. An issue which every previous speaker has mentioned that has to do with the quality of the curriculum. For example, we have now in existence hundreds, maybe thousands, of CAI lessons that have not been validated. Most of them have been written by classroom teachers and/or their students for use in their own narrow environment. There is, at present, no way for a prospective user to know if these lessons do what they purport to do or even if they "run" properly. There exist almost no curricula, that is, groups of related courses.

3. Concern about information about information technology. The public needs to be informed of the impact of information technology in the schools and in their own world. Educators need to be informed about the availability of materials and the uses of such technology to improve both its accessibility and effectiveness and to reduce their fears in regard to job security and the dehumanization of education.

4. Perhaps the most important concern is that the private sector already has a foothold in all the school systems of this country, and we need to move quickly to prevent a catastrophic purchase of misunderstood, misused, and misrepresented devices and associated courseware. In a new field that lacks direction and standardization, school systems are ill equipped to examine and evaluate sophisticated devices, exaggerated claims about curriculum, and promises of economic savings and increased academic achievement.

Though the Elementary-Secondary Education Workshop has very few, if any, specific recommendations to resolve the concerns and questions raised above, we generally urge the Federal Government to encourage the incorporation of contemporary information systems in public education.

More specifically, we offer the following suggestions:

1. Grants, categorical grants to help narrow the differences between the "haves" and "have-nots" in terms of acquiring hardware and software. In addition, these grants could include requirements that would make subtle but important changes in the direction that the growth of information technology is now taking. These subtleties could be clauses requiring validation data of courseware or curriculum software, evaluation, and description of previous uses of such software, cost effectiveness data, and so on.

2. Increased NSF, ESEA, and other grants specifically aimed at providing teacher and administrative preservice and inservice training and retraining in the areas mentioned.

3. Federal support of a network of State and local agencies—some already exist—that would serve a role in evaluation, validation, and dissemination of information regarding hardware and software in this new and ever-growing field.

4. A tax incentive program to encourage the role of private institutions in the application of information technology in public education. Many possibilities exist such as the exchange of personnel with school systems, sharing of equipment, loan of personnel, and so on.

I would like to close these remarks without making more specific recommendations. To create a long list of possibilities would serve no useful purpose but rather would clutter an already confusing field. The four recommendations above are economically conservative, philosophically realistic, and in line with the Federal Government's past role in education. They would require no significant changes in the direction of Federal involvement in education nor would they require the adoption of radically new legislation.

Finally, on a personal note, I hope I have spoken for all of the members of Elementary-Secondary Education Workshop with integrity and responsibility. I urge all those listening or reading this document to keep in mind the talent in the public schools of this country. Too often, the elementary and secondary schools have been left to implement programs developed elsewhere resulting in a lower achievement of the goals set forth during the planning of such programs. Embracing the professionals in the public schools as equal partners in the planning and development of educational enhancements such as the application of new technologies can and will result in more realistic programs and greater achievement.

Mr. **Brown**. Thank you very much, Dr. Litman.

At the risk of saying something that will discourage the succeeding chairmen, I want to say to Dr. Litman that that very succinct summary was of tremendous value to me. It seemed to me to present the key issues in a very logical, well-thought-out way, and I am not sure whether that reflects the fact that you had an unusual group that thought logically and came to conclusions or whether you just digested it well. But I was very much helped by that presentation, Dr. Litman, and I want you to know that.

We will take one or two questions, and I will try to be as disciplined as possible about that. Would anyone care to ask a question that would help to clarify this report? I will not force this opportunity on you, of course.

There being no questions we will proceed to the next report.

The Postsecondary Education group was chaired by Dr. Karl Zinn, a research scientist at the Center for Research on Learning and Teaching, and we welcome you Dr. Zinn.

POST-SECONDARY EDUCATION: PRESENTED BY DR. KARL L. ZINN, CENTER FOR RESEARCH ON LEARNING AND TEACHING, UNIVERSITY OF MICHIGAN

Dr. ZINN. The working group on Postsecondary Education has prepared a comprehensive and well organized statement which speaks for itself. So I would like to call your attention to the personal nature of the benefits—or the negative side effects—of increased use of information technology in education. Indeed, each of us should think through those experiences which define the personal dimensions of the effects of what we have now proposed at these hearings. The measure of success of new programs for information technology in education should be taken not just in terms of dollars, or units of equipment, or numbers of students exposed to computers, or the quality of the curriculum materials. We have to consider the impact on people and on their lives, the secondary effects as well as the intended primary ones, and the negative as well as the positive.

The efforts of our working group were very productive, and we were assisted most effectively by staff at all levels. Typists helped us through three successive drafts of our recommendations and arranged duplication so that all members of the postsecondary group have in their hands a current copy of the statement which we would like to enter into the record. But for the time limitation, I would tell how information technology could have eased the burden on staff and participants as we worked together to deliver a useful formal statement which all of us could support.

In my informal statement, I would like to represent some of the substance, without reading from our written recommendations, and convey some of its significance as reflected in my personal experiences. However, each of you will have to look into your own experiences for corresponding feelings of satisfaction or frustration, and make your own judgments about impact of information technology on postsecondary education.

It need not be stressed that the general public recognizes the explosion in technology and information as a problem. But we in higher education must take as a challenge and an opportunity the need to guide these developments, and to help integrate them into the domain of education and training throughout society. The new technologies introduce qualitative changes in our intellectual lives which will have widespread impact on society and individuals.

Professor Licklider, in his testimony before this subcommittee yesterday, characterized the improved access to information resources from the perspective of an individual student in the 1990's. I have seen such students in Ann Arbor, some of them dropouts, or nearly, from the local schools, discovering the wealth of information and leverage of information processing available to them through new technologies—students who are taking new initiative for their own learning, communicating by means of computer aids with other learners, practitioners, and scholars. In my daily work I share an information system such as Licklider described, although so primitive in comparison you might not recognize it as conceptually similar. I have, however, experienced the joy of learners of all ages sharing their explorations and have observed the appreciation of college professors for written contributions to a computer-based seminar made by participants they have never seen, participants whom only I knew still to be in high school.

Our working group stated unambiguously the need to provide access to underrepresented groups: social, economic, and ethnic minorities; women; handicappers; and the elderly. I could tell stories about information technology in education concerning friends and associates in each of these categories, and probably many of you could as well. It should be enough to sketch for you one instance in which the opportunities for communication, education, and a career opened up for a student in a class I taught in Grand Rapids. He came in a wheelchair without voice or keyboard to communicate with me. He now carries on his chair a personal computer which provides spoken voice and text display, and it allows him to enter, organize, and retrieve information as he needs it for communication, study, and professional work. Already a good computer programmer, some day he will be an excellent system designer.

Jim carries his personal computer with him on his battery-powered wheelchair. So his computer also needs to take its power from the battery and be rugged enough to handle the range of temperatures and moisture wherever he goes. It needs a large memory to store the vocabulary of words and phrases he would like to speak, as well as computer programs for personal convenience, and information to have at hand.

A voice synthesizer has been added to the computer so that whatever Jim wants to say can be spoken by the machine. He assembles words and phrases, directing his computer with a foot pedal, since that's the part of his body over which he has good control. The text of what he wants to say appears on a small screen mounted on the arm of his wheelchair. When it's right, and when he has the attention of his listener, he directs the computer to speak, at a normal rate, the entire utterance. It might be just "How are you?" or it could be the speech for a national conference on communication aids for handicappers.

Jim has a fine mind, and his brain works well in all respects except motor control. He is a student at Grand Rapids Junior College and plans to attend Michigan State University next fall. One of his current interests is design of information systems. Probably he'll have a chance to work at the artificial language lab at MSU, the same group that helped him gain a voice.

An important point to make is that the same technology that helps us communicate for recreation, or for business, may be a necessity for someone who has been denied some basic medium of communication such as speech. But further, and this is more subtle, what is learned from helping those with severe handicaps often can be applied by helping the rest of us with our minor handicaps.

Higher education will take a leadership role in education and training, now going directly to the public as well as carrying on the institutes and regular academic programs which have been helpful in the past. Computing technology is advancing rapidly, and the industry is pushing new products too fast for people to master them, with new markets opening up, increased expectations about computer use in many jobs, and accelerating sales of small computers to homes, offices, and schools. Again reporting my personal experience, which must be similar to that of many of you here today, teachers and administrators from schools and colleges are seeking help in whatever form can be arranged quickly and economically. Without more resources, the universities in my State cannot respond effectively. The technology and its marketing far exceed the available programs for faculty development.

Dr. Heuston, Dr. Johnson, and others presenting testimony during these 2 days of hearings emphasized the importance of quality curricula in acceptance of new technologies. Federal programs are needed to encourage development and validation of exemplary curricula, software and systems. Long-term research will extend modes of communication possible between learner and information systems, and among learners using the systems.

Information will be represented with improved graphic and audio means, using networks and other three-dimensional and dynamic structures. Computer assistance will help learners arrange multiple views of text and graphics. Problem-solving skills will expand in more directions than can be anticipated. Artistic creations will similarly be extended beyond our present abilities to comprehend and appreciate. I know young designers who are discovering new opportunities, and I have seen the world of creative design and music composition opened up to those previously excluded by lack of skill or by physical handicap.

Dissemination of information and ideas about technology in education received thoughtful attention in the recommendations of our working group. We attempted to deal with the need for transfer between disciplines and throughout communities of researchers, and from the laboratories to the classrooms. A story I cannot take time to develop involves my participation in a research community even while traveling this week. Last night in my hotel room I stayed up an extra hour or two to interact with people I work with who also use the University of Michigan computer for writing and communication. I hooked up my portable (that is, a user console) by telephone, making a local phone call into a national data network that easily connects to the Michigan network and into my university's computer. In addition to carrying on some university business by electronic mail, I obtained comment on the background material for our working group which I had posted on an "electronic bulletin board" earlier in the week. And next week I expect to collect comment on the group report we submit today, using the same electronic communications (some call it computer conferencing) to extend the reach of our working group.

Our recommendations include a number of specific and immediate actions. If I had time I would tell some stories about how clarification and perhaps change of some regulations bearing on copyright, communications, and educational subsidies could do much to help development of important new tools from information technology for education and training. For example, I know people with excellent ideas and innovative products who are giving up for lack of copyright protection.

I should like to close my personal remarks by reminding each of us to think about the important themes that have been treated in the testimony at these hearings, and in our own working groups. For example, I am particularly concerned about access to information resources, quality of materials for education and training, and individual initiative and responsibility.

Furthermore, I should like to remind us to explore the resources that will be needed to meet the challenges. I am especially interested in making good use of the people resources which are so important to maintaining human values and humane use of technology.

We should also review the recommendations of hearings in 1978 and 1977, and recommendations of study groups published in 1975, 1972, 1970, 1967, and 1966. Useful information and good advice have been accumulating for over 15 years; we are developing some consensus on what needs to be done. Clearly, it is time for action, but more actions than can be carried out by Congress and the executive branch. Each of us should assume some responsibility for carrying the important ideas back to our own communities and into our professional circles where they will do much good for education through the wise application of information technology.

Thank you.

[Applause.]

The final report of the working group on post-secondary education follows:

REPORT OF WORKING GROUP II: POST-SECONDARY EDUCATION

INTRODUCTION

An explosion in technology and information is recognized by the general public as a problem, but should be taken as a challenge and opportunity for higher education in the United States. The rapid growth of information technology needs to be managed and put to use rather than just left to continue unguided. Working with future leaders and trainers, leaders in higher education have a unique opportunity to guide the latest technological developments and help them expand into and become integrated with the larger community. This will require cooperative effort among all levels of education and various governmental bodies.

Information society

The application of new technology has become more than a matter of replacing old tools with new, speeding up the transmission of information, and changing the video picture from black-and-white to color. The new technologies introduce qualitative differences into education and society, just as the automobile and airplane changed more than the rate of travel; but the qualitative changes in our intellectual lives will be of more widespread impact on society and individual well being.

Our society is becoming an information society. Already we witnessed the shift in workers from farm to factory, and now from factory to services and the knowledge industry. The shift to the new society provides higher education with several challenges.

(a) To improve the effectiveness of education through the use of the new tools for information technology;

(b) To confront the issue of social change through research contributions; and

(c) To provide leadership (and train new leaders) for the transformation from industrial to knowledge society.

A significant benefit will be improved access to the total information resources of higher education—intellectual as well as technological—through the new information and communication technologies. At the same time we must aid in identifying the potential abuses and the factors which may limit the productive use of information resources.

The government, working with institutions of higher education to provide access to information technologies for underrepresented groups (handicapped, elderly, women, and social, economic, and ethnic minorities), needs to ensure that existing opportunity gaps disappear rather than widen.

For the benefits of information technology to be realized in our society through an orderly process, higher education has an essential role to play involving research, teaching, and service functions.

IDENTIFICATION OF ISSUES AND GOALS

Education and training

The primary needs for education and training regarding information technologies are:

(1) To develop leadership in all departments of each college and university in using information technology;

(2) To train the faculties who educate primary and secondary school teachers;

(3) To provide continuing education for teachers in the field who are expected to incorporate use of computers into instruction;

(4) To provide education for adults and their children to make effective use of computers in their personal lives; and

(5) To provide education for those who make decisions and set policy (including the private sector as well as the public), giving special attention to understanding the dangers as well as the opportunities of the technology.

One activity requiring federal funding is the holding of summer institutes on innovation in teaching with specific emphasis on the application of information technology. Some institutes would emphasize specific disciplines and others certain technologies. One of these institutes should focus on evaluation of effectiveness.

Another set of institutes would address the continuing education needs of public school teachers and those administrators who wish to incorporate the use of information technology into their classrooms and schools. The administrators need assistance in deciding which system to purchase or to rent, and in guiding effective use with students.

Finally, in an effort to provide wide public access to computers and information technology, we recommend the establishment of information centers in locations such as public libraries. These would provide assistance for: (1) access to information resources in educational institutions, libraries and the private sector; (2) use of computers for self-education; (3) use of government procedures and documents (IRS regulation, qualifications for food stamps, etc.); and (4) use of computers for fun.

Long-term development and research

Testimony emphasized that the availability of quality curricula will determine the extent to which the new technology will be integrated into the learning process. The Federal Government should establish support programs through existing agencies such as the National Science Foundation and the new Department of Education to encourage research, development, and validation of exemplary curricula, software and systems.

We define exemplary curricula to include a statement of the learning strategy employed, content, mode of presentation and mechanisms for evaluation. Software is the vehicle through which the curricula can be imbedded in and delivered by various forms of information technology. Systems include combinations of software and hardware products to facilitate lesson development by all interested instructors. The specific form of the funding program is not critical, but it should consider funding individuals, private corporations, non-profit organizations, and institutions of higher education. Possible funding approaches should encompass grants-in-aid, guaranteed loans, contracts, tax incentives, etc. This funding should be provided on a continuing basis so that long-term development and research can be supported.

The uses of an open university as a development center for information technology in education should be explored.

Dissemination

Federal programs should facilitate the dissemination of information technology systems to accelerate the flow of R&D findings into education. A dissemination program should include investigation of the factors which enhance or hinder diffusion of the new technologies.

Dissemination should also foster technology transfer between disciplines and among different groups of people and the transfer of technology from the research laboratory to the classroom.

The Office of Dissemination (under the Assistant Secretary for Research and Improvement) in the Department of Education could be charged with the responsibility for these activities, working with the agencies supporting specific programs.

Availability of resources

Federal programs should support equipment needs in the use of information technology in higher education. Information technology projects or programs that involve large initial capitalization or large investments are beyond the ability or inclination of support by one or a few schools. One example is the provision of satellite services for nationwide delivery of information technology service.

Federal policies should encourage private agencies to provide resources to higher education by providing motivating benefits. One possibility is in the area of special tax relief for equipment gifts to universities, provision of access to facilities or assistance of specialized staff. Another area is special concessions to encourage cable operators to supplement university services with additional equipment and/or facilities.

SPECIFIC AND IMMEDIATE ACTIONS

Demonstrations

Many compelling applications can presently be brought together to demonstrate the potential of these information technologies for education. These demonstrations require the investment and participation of more than a few educational and management institutions. We recommend that the Federal Government facilitate large scale demonstrations of combinations of information technology. For example, there is a need to explore on a larger scale the application of computer technology in combination with videodisc, satellites, cable, and other informational technologies. Structures for systems of interinstitutional cooperation also need to be explored.

Regulation, laws, and procedures

A Federal task force should examine existing regulations to determine how these regulations can facilitate the realization of the identified goals and how these regulations might, in fact, inhibit their achievement. These regulations include tax laws, copyright laws, communications regulations, antitrust policies, educational subsidies, and existing agency practices.

Ongoing studies and activities

The Federal Government, through appropriate actions of both Congress and the Executive Branch, should formulate specific programmatic efforts including ongoing surveys and studies to accomplish the above goals.

These programmatic plans should include the submission of reports to the Congress at suitable intervals from the concerned agencies in the Executive Branch: the Department of Education, the National Science Foundation, the Advanced Research Projects Agency, the Office of Naval Research, and the Army Research Institutes. These reports to Congress should include the establishment of programs for support of the above goals.

Since this field is changing so rapidly it is essential to have ongoing studies of the uses of information and communication technologies in higher education and to inform the public of the potential of these new technologies. The leadership role in the conducting of the surveys and studies should be taken by the National Science Foundation and the Department of Education with the advice and consultation of ONR, ARPA, ARI, NTIA, and other relevant Federal agencies.

Mr. **Brown**. Thank you very much, Dr. Zinn.

I know the shortness of the time prohibits covering everything that needs to be covered, but you will have the opportunity to amplify in a written report which will go into the permanent record.

Any questions of Dr. Zinn?

All right—I am not trying to frighten you, if you really have some questions.

[No response.]

Mr. BROWN. If not, I will deviate slightly from the order and call on Mr. Joseph Becker to report on the discussion group on Public Planning for the Information Society.

I am happy to welcome Mr. Becker who I just found out is practically a neighbor of mine, since he comes from southern California also.

We are looking forward to hearing your report, Mr. Becker.

PUBLIC PLANNING FOR THE INFORMATION SOCIETY: PRESENTED BY JOSEPH BECKER, PRESIDENT, BECKER & HAYES, INC.

Mr. BECKER. Thank you, Mr. Brown.

Good afternoon, ladies and gentlemen: I must confess that I got into the field of information technology by mistake. And, what is worse, it was a machine error.

In World War II, I was a tank platoon commander going to Italy. Somehow the Pentagon coded my IBM qualification card as if I were a Japanese linguist. When the punched card error was discovered, rather than admit it, they put me in charge of certain intelligence information files plus a room full of IBM machines.

I applied the machines to the information and thus, in 1946, began my interest in information technology.

I have watched the field grow over the years and am pleased to be here today to tell you about the findings and conclusion of Working Group 6.

What we did before we began our deliberations was to try and summarize what we heard at the conference during the last 2 days. Let me share our list with you:

First, information technology amalgamates three technologies: Computers which can process information very fast; communications technology, which can distribute information more widely than ever before; and audio-video technology, which combines the various media into a single format. The convergence of these individual technologies, we were told, is creating a new information environment in our country affecting not only our educational systems but also other aspects of our national life.

The role of the teacher is changing. He or she must learn to understand the new information technology and find ways of applying it.

We heard that information technology may be ushering in a new age, an information age, and as Daniel Bell tells us, an increasing share of the GNP is being devoted to the production of knowledge.

We also heard about the collapsed time scale of technological change. Change is occurring so fast today that we hardly have time to plan. An information technology generation is now measured in terms of 14 months.

Another point developed during the conference was that information technology is the handmaiden of productivity. It provides us with a chance to augment national growth. We also heard that information technology deserves a high national priority, and were told that the Congress is more aware and more interested in the topic than ever before. Some at the conference felt we should begin treating information as if it were a national resource.

Information technology isn't coming, it's already here. It is happening in spite of all other factors and it will soon be democratized. The word "democratized" was used over and over again. An interesting article appeared in this morning's Washington Post. It describes how the microprocessor "chip" will democratize information technology in the United States.

Working Group 6 talked about the technology. We concluded that information technology is apt to touch people three ways:

First, it affects the way citizens access information resources, whether by networks or other ways, it implies greater control over content and quality. Adopting unwise policies now could cause great inequities in terms of who is able to access what in our society.

Second, as far as the technology is concerned, it brings information directly into the home in an interactive sense. Every den in a house is a potential home information center. Personalized TV instruction may very well bypass traditional school methods as individuals in the home choose the things they want to learn.

Third, technology equates with microprocessors. The semiconductor chip can develop significant educational abilities. Something new in education is coming along, we don't know what, but we have a feeling it relates in some way to the television set, the home, and intelligent terminals.

"What is the problem?", we asked. Well, unless information technology is introduced responsibly, we will miss a great opportunity in this country. Unless we face the problems presented by information technology, we risk losing the technological advantage we now possess. Unless we act with dispatch we are in danger of introducing incompatible systems of machines, rather than systems of high educational quality.

Information technology is not just another Government problem. It is a national phenomenon. One that is multidimensional and cuts across all aspects of our Government and national life.

The application of information technology to education raises difficult questions: Will emerging systems be compatible? Will users be charged for the information they access and use? What is the role of the Federal Government? Are community research centers to be encouraged? In what ways will the introduction of new information technology change the traditional structure of American education?

These questions have been asked before, and even asked before the Congress, but they have not been adequately answered. A national policy is needed and our working group identified the following issues as being important for congressional attention:

The first is creating a nationwide network. Dr. Zinn spoke of this. We need a focal point to coordinate and facilitate the deployment of educational information networks. We need to insure that such networks are broad-band, nationwide and accessible to all segments of the population. We need to interconnect our schools, libraries, and other centers so that they become interdependent partners in the sharing of knowledge.

The second issue is defining or planning the Federal role. We need to designate an entity in Government and assign it responsibility for designing and developing policy on the utilization of information technology in education.

As recognized by our group, these problems involve many Federal agencies and many segments of the public and private sector. All of the interests of all of these parties must somehow be represented. Information technology competes with traditional forms of delivery in its effectiveness and social consequences. Accordingly, evaluation techniques which take into account both economic and social consequences as well as the quality of materials must be devised.

So our first two issues were: creating a network, and defining the Federal role. The third issue we discussed was equalizing access to knowledge.

Everybody, regardless of his or her geographic location or economic circumstances must have an equal opportunity of access to knowledge. We need to apply the same legal and statutory language which has governed the development of public education in the United States to information technology.

The fourth social issue is protecting intellectual property and encouraging the private sector investment. We need to devise means for compensating authors and publishers. We need to insure that such protection does not restrict citizens from enjoying the maximum benefits offered by the new technology. We need to enunciate principles promoting the creation of educational products and services of high quality. And, we need to encourage the private sector, to continue to invest in technology as it has and is currently doing.

The issue of standards was also discussed. Our group felt that we needed involuntary standards to guide the compatible development of technology without inhibiting innovation, a most difficult assignment for any legislating body.

Another issue: Consolidating information about information technology. Because developments are occurring so fast, we need to establish some kind of a clearinghouse. Some thought this should be an "on line" data base available through a computer network or service. The clearinghouse would also play a role in the development of educational applications in information technology. We believe such a clearinghouse would reduce a good deal of redundant effort, and that the need for such a clearinghouse is critical.

What initiatives do we suggest for the Congress? We recommend the following steps be considered:

We recommend that the Congress create a permanent national commission on information technology. There is a bill before the Congress to do this but I don't believe it calls for a permanent commission. The commission could provide a forum for formulating and deliberating relevant national policies and for monitoring policies once they were in effect. No such forum currently exists.

We recommend the Congress advise the Secretary of Education of the potential significance of information technology to education and that funds be provided for relevant studies, demonstrations, clearinghouses, et cetera.

Our third suggestion: We recommend that a person experienced in the field of education technology be appointed to serve on the Intergovernmental Advisory Council of Education. This is the new body which will advise the Secretary of Education.

Next, we recommend that new legislation be drafted that will enable libraries to form a national network of knowledge, and that the interstate portions of this network be funded and coordinated by the Federal Government.

And finally, we recommend that the Congress designate a small group, perhaps a subset of this group, to meet again in 3 months time—we can't wait a year in this rapidly evolving field—to report on progress and provide whatever input would be beneficial to the Congress.

The above constitutes the sum and substance of Working Group 6 deliberations.

[Applause.]

[The final report of the working group on Public Planning for the Information Society follows:]

REPORT OF WORKING GROUP VI, PUBLIC PLANNING FOR THE INFORMATION SOCIETY

Information technology amalgamates the capabilities of computers, communications, and video. Computer technology enables information to be processed at high speeds; communications technology provides the means for distributing information widely to people and institutions; video technology allows information, sent from afar, to be presented in a convenient audio-visual format.

Currently these technologies are converging rapidly to change dramatically the way information is stored, retrieved, sent, manipulated and received. The possibilities for their application to education are innumerable and complex. Some theorists believe that technological change will usher in a whole new Information Age. And, how information is handled in this country, they say, will determine to a large extent the quality of the decisions our people make and the nature of the lives they lead. The task at hand is to choose responsibly among these varied options, so that we will not only be able to live with, but also to benefit maximally by the technology we emphasize.

One way to organize the nation's disparate educational information systems would be to create an electronic network to interconnect them. Though the transmission of information over a network has been considered costly, new developments in communications such as fiber optics, packet switching, and direct broadcasting satellites portend lower communications costs. As more and more electronic arteries are established between libraries and educational centers, the total knowledge resources of the country might one day become utterly accessible to students and educators no matter where they live.

But even a commitment to a national knowledge network does not greatly simplify the challenge of choice. In the future, information in educational settings will be manipulated and permuted as never before. These changes relate chiefly to the developments that continue apace in the computer field. Computer manufacturers are already building "intelligent terminals". These have greater stand-alone power and memory than their antecedents. For example, they will most likely be able to accept instructions, perform tasks at pre-designated times, and revise heuristic strategy as research progresses.

In time, it is conceivable that virtually every student will have access to an intelligent terminal, perhaps no larger or more expensive than a personal calculator. It will put both computing power and communications capability at his fingertips. If not a brain and communications center in every hand, then one in every home: not to be outdistanced by developments in computers, elements of the burgeoning home electronics industry are readying a line of interactive terminals that will bring knowledge resources directly to the den. It is possible, eventually, that every home TV set will be uniquely addressable, like the telephone, and the time-sharing of videodisc memories will become commonplace.

Obviously, such changes in information technology and its application to educational endeavors will generate difficult issues of public policy. Which systems are most useful? Can they be made sufficiently compatible? Will users be charged for the knowledge resources they access in a society that has traditionally held information to be a public good?

What is the role of the federal government in the deployment of networks? Are community resource centers to be encouraged as well? In what ways will the introduction of new information technology change the organizational structure of American education?

Though these questions have been asked before, and asked before the Congress, they have not been adequately answered. A coherent policy, consequently, has yet to be devised. Toward giving Congress a better grasp of these questions, our Working Group was convened, and from its deliberations offer this report.

1. BACKGROUND

(a) Information technology amalgamates the capabilities of three subtechnologies—computers, communications, and audio-video technology.

(b) Convergence of these technologies is leading to a totally new information environment in the country which is affecting education and other components of our society.

(c) The role of the teacher is changing.

(d) Technological change is ushering a new age, an Information Age—an increasing share of the GNP is going towards the production of knowledge rather than for the production of goods.

(e) The collapsed time scale of change forces us to act rapidly. We must choose options responsibly, and to be especially sensitive to citizen needs.

(f) Information technology is the handmaiden of productivity. It provides us with an opportunity for augmenting national growth and raising the education level of the people.

(g) Insuring the effective use of information technology deserves a high national priority. At present, its introduction is occurring without plan and without national over-sight. We need to begin treating information as a national resource and benefitting from the application of information technology.

(h) Information technology isn't coming, it's already here. It's happening in spite of all other factors—and it will soon be democratized as instruments and applications become cheaper, smaller, and more useful.

2. THE TECHNOLOGY

(a) Technology touches our people in three ways: It affects citizens' access to the total national information resource through networks and implies greater equality of access to education. However, unwise policies could cause inequities. Brings information directly into the home—in an interactive sense. Every den becomes a home information center. Personalized instruction may by-pass traditional educational systems. Provides microprocessors capable of delivering varied educational capabilities through personalized intelligent terminals.

(b) The convergence of these technologies is an added dimension in educational practice. It will make possible an increased emphasis on personalized instruction. The power of information technology lies in its ability to enhance the teaching-learning process while also being cost/effective.

3. THE PROBLEM

(a) Unless information technology is introduced responsibly—we miss a great opportunity.

(b) Unless we face the problems presented by information technology—we risk losing the technological, and therefore competitive advantage we now possess.

(c) Unless we act with dispatch—we are in danger of installing incompatible systems of mixed rather than high quality.

(d) We are not dealing with just another new government mission in education. We are dealing with a phenomenon—one that is multidimensional and cuts across all aspects of our government and national life.

4. THE ISSUES

(a) *Creating a nationwide network*

We need a focal point in government to coordinate and facilitate the creation and deployment of educational information networks.

We need to ensure that educational information networks are broadband, nationwide, and accessible to all segments of the population.

We need to interconnect our schools, libraries, and other informtaion centers so that they become interdependent partners in the sharing of educational information and knowledge.

(b) Defining and planning the Federal role

We need to designate an administrative entity in government and assign it responsibility for designing and developing policy for the utilization of information technology in education. (It is recognized that these problems involve many federal agencies and many segments of the public and private sectors. All interests must be represented in any emerging administrative structure.) (Information technology competes with traditional forms of delivery in its effectiveness and social consequences. Accordingly, accurate assessment techniques which take into account both economic and social consequences must be devised.)

(c) Equalizing access to knowledge

We need to introduce information technology into our American society in ways which avoid elitist use. Everyone, regardless of economic circumstances, social condition, or geographic location must have equal opportunity of access to knowledge.

We need to apply the same legal and statutory language which has governed the development of public education in America to information technology.

(d) Protecting intellectual property and encouraging private sector investment

We need to devise workable means for protecting intellectual property and compensating authors and publishers for their works.

We need to ensure, however, that such protection does not restrict citizens from enjoying the maximum benefits offered by the new technology.

We need to enunciate principles promoting the creation of educational products and services of high quality.

We need to encourage private sector investment in information technology.

(e) Developing standards

We need to evolve voluntary technical and performance standards which will guide the compatible development of information technology without inhibiting innovation.

(f) Consolidating information about information technology

We need to establish a clearinghouse, preferably through an on-line computer network, that permits educators, information system planners, and others, to stay abreast of new developments and play a role in the development of educational applications in information technology.

We believe a clearinghouse for information technology would reduce unnecessary duplication of effort. The need for such a clearinghouse is critical because new developments in the information technology are occurring so rapidly.

5. INITIATIVES FOR THE CONGRESS

We recommend that the Congress create a permanent National Commission on Information Technology. Also, that the Commission provide a forum for public and private sector deliberation of national policies; and, that it be assigned responsibility for monitoring such policies once they are in effect.

We recommend that the Congress advise the Secretary of Education of the potential significance of information technology to education and that funds be provided to the new department for relevant studies, demonstrations, clearinghouses, etc.

We recommend that a person experienced in the field of information technology be appointed to serve on the Intergovernmental Advisory Council on Education.

We recommend that new legislation be drafted that will enable libraries and other education centers of information to form a national network of knowledge and that the interstate portions of this network be funded and coordinated by the federal government.

We recommend that the Congress designate a small group, within the present membership of the workshop, to meet again in three months to report on progress.

Mr. Brown. Thank you, Mr. Becker.

I am going to again recognize anyone who might have a question.

[No response.]

Mr. Brown. If not, we will go back to Group No. 3, Special Education, and recognize Dr. Donald V. Torr, who is assistant vice president for educational resources, Gallaudet College here in Washington.

SPECIAL EDUCATION: PRESENTED BY DR. DONALD V. TORR, ASSISTANT VICE PRESIDENT, COLLEGE OF EDUCATIONAL RESOURCES, GALLAUDET COLLEGE

Dr. Torr. Thank you, Congressman Brown, for sponsoring this seminar. I appreciate the opportunity to be here and to meet with the discussion group and all other attendees. I would like to acknowledge the efforts of the discussants in the special education discussion group. Everyone participated and the discussion was valuable.

Mr. Chartrand asked that the discussion leaders summarize the discussion by specifying issues and recommendations. Before specifying issues I would like to say, on behalf of the special education group, that we were concerned about some of the presentations which were made on the subject of computer-aided instruction. One might infer from some of the remarks made that CAI was the answer to the educational problems we face today. Costs related to CAI were shown as falling and the potential of CAI was described in very positive terms. We agree that CAI can serve a very useful function in education, but urge that it be seen as one tool among many which can be used by the teacher. There are some tasks which can well be assigned to the computer; however, it is unlikely, for example, to serve as a good role model or to help a student develop successful social skills. We also questioned one element of cost. While hardware costs are falling, the cost for the development of instructional software is not. Lack of software has been the major problem to date. It is not clear that a funding base for significant instructional software development exists today.

It is important, I believe, that we not confuse information technology and educational technology. I believe that has occurred during our seminar. To me educational technology is any technology arising from basic research in the physical and behavioral sciences which can be used to contribute to the solution of an educational problem. I see information technology as any technology which can be employed to effect the emission, transmission, storage, processing, or reception of information. Much information technology can be employed as educational technology; this is especially true when dealing with special education. In dealing with educational problems, however, we should not consider information technology as providing the full solution set.

Now I will turn to the issues identified by our group. One issue is the need to insure that as new technology becomes available the needs and rights of handicapped individuals are not forgotten. As an example of what can happen in information technology we can consider television. Exploitation of this technology started some 34 years ago. Only this year, however, has it become possible for deaf individuals to begin to see some programming on commercial stations which they could comprehend because the programs have been captioned using the unobtrusive technology of closed-captions.

Another issue discussed was that individuals need to understand that technology is not all-powerful in spite of the fact that "technology" made it possible for men to land upon the moon and return. It is not possible today to automatically encode continuous speech, for example. Such a capability would be of supreme value to persons who do not hear, but it does not exist today.

Another issue, wh[illegible] I think, not debatable and therefore might better be labeled a pr[illegible]lem, is the point that, while the needs of special education for the application of information technology and other technologies are great, the market is too small to make the area commercially attractive.

Another issue for consideration is the need for a noncommercial centralized consulting base of persons who are knowledgeable of information technology and who can quickly assist problem solvers who do not have the time to search for all relevant technology. These consultants hopefully would have been able to obtain objective information from the manufacturers as to what their equipment can truthfully be expected to do.

Still another issue is the need for validation data in the promotional literature of equipment manufacturers. Data should be provided which specifies the conditions under which the equipment has been tested and shown to do what the manufacturer claims.

Turning to recommendations, the special education discussion group recommends that special educators themselves make it a practice to involve equipment manufacturers or software developers as early as possible in their efforts to develop solutions to special education problems. It may be that in so doing we can find ways to use their products with minimal changes, thus avoiding the high costs associated with modifications for special education students.

Another recommendation is that special educators meet and agree upon problem statements which can be used to stimulate problem solvers who know the technology available.

With respect to the development of initiatives to encourage interest in the small special education market we recommend that the explorations which have been initiated by Congressman Brown be encouraged. I refer to meetings which have been bringing together members of the public and private sectors to discuss such matters as: Financing incentives, patents and licensing, market research, and standardization. We urge that the unique need for incentives associated with development for handicapped individuals be emphasized in those discussions.

We recommend that the subcommittee explore with the Department of Education the need to establish an independent base for technical support in the field of information technology. This support should provide access to persons who possess state-of-the-art knowledge, who are unbiased and factual, and who can assist persons in special and general education who are attempting to design systems to meet specific educational needs.

We recommend that the private sector devote time to the development of increasingly sophisticated information processing techniques for CAI to provide more than the "information presentation, example, test, and branch" paradigm. In the education of deaf students, for example, automatic analysis of the language entered into the computer by deaf students would be highly useful.

I would like to refer to issues once more. The issues are not limited to information technology but apply to problem solving on a national scale. We have throughout the country an immense resource of knowledgeable persons in legislatures, laboratories, industrial complexes, business houses, and universities. We have immense problems. Our approach to these problems often seem chaotic. An issue is the need to establish a means for solving them such that rather than behaving with the efficiency of the typical light source, with scattering and reflection in every direction, we have the highly focused common direction of the coherent light of the laser and the information carrying capacity which that affords us.

Thank you. [Applause.]

Mr. **Brown**. Thank you, Dr. Torr.

Are there any questions of Dr. Torr?

[No response.]

Mr. **Brown**. All right, next we will go to Group No. 4, Adult Education, which was chaired by Dr. Milan Wall, executive vice president of the University of Mid-America.

Dr. Wall?

ADULT EDUCATION: PRESENTED BY DR. MILAN WALL, EXECUTIVE VICE PRESIDENT, UNIVERSITY OF MID-AMERICA

Dr. **Wall**. Thank you, Mr. Brown. We, too, had a hard-working group, and we just wanted to say before I went into our statement how much we appreciate the work of the professional and clerical staff of the two committees, and the staff of the Congressional Research Service which provided a nice organizational structure within which to work.

Our statement is divided into three sections: The first is a kind of premise or overriding statement about adult education, and its relationship to information technology; the second is a series of issues that need to be addressed; the third is a series of recommendations.

First, the statement of belief. Until fairly recently, the rate of change in our society was sufficiently low that the traditional concept of education—as something needed by children and young adults prior to their entry into the work force—was adequate for the vast majority of citizens.

We now recognize, however, that the pace of change in our society—including increased rates of knowledge and more efficient means for disseminating that knowledge—has increased dramatically, and it is likely to increase in the foreseeable future.

Therefore, we feel it is incumbent on government, as well as the private sector, to review the current model of education.

We believe such a review will lead us to the conclusion that these societal changes demand a reconceptualization of the educational model in order to achieve a situation in which continuing education for adults—both informal and formal—is encouraged and facilitated. In the previous decade or two such a review might have been only an exercise, because we lacked the means to implement such a new model.

It is our belief now that the communication and information processing technology are at hand, and that Congress must carefully consider earmarking or redirecting funds for the purpose of supporting efforts to design and implement technology that will aid and abet continuing adult education in both the formal and informal settings.

We went from that statement, I believe, to identification of a series of issues, and those are as follows:

Issue No. 1: Relatively little is known about how adults learn, why they are motivated to learn, and how to motivate them to overcome personal barriers to certain kinds of learning.

Issue No. 2: Insufficient financing is available for development of educational software and acquisition of hardware for adult education.

Issue No. 3: Barriers exist to availability of financial aid for adult learning in nontraditional educational programs.

Issue No. 4: Insufficient standardization of hardware and software specifications makes usage difficult across product lines.

Issue No. 5: Telecommunications agencies do not pay adequate attention to educational users.

Issue No. 6: Government regulation and practices tend to favor traditional curricula.

And issue No. 7: Government attempts to enhance equity for disadvantaged younger students have not been very successful, and we believe there is a danger the same record may extend to this segment of our older population.

Now for our series of recommendations, some of which go nicely with the issues, and some of which don't.

Recommendation No. 1 deals with our knowledge about how adults learn and related issues, and our recommendation is that various Government agencies that deal with adult learning considerations, among them USDA, NIE and the military, should direct more resources to research efforts to find out how adults learn, and why they are motivated to learn.

Recommendation No. 2: We proposed studying the feasibility of the creation of a tax on certain technologies in order to support development of such technologies for the public benefit.

Recommendation No. 3: Barriers that exist to the availability of financial aid should be removed so that adult learners may benefit.

Recommendation No. 4: We believe that the Federal Government should encourage compatible hardware and software systems to further broaden the applications of those systems.

Recommendation No. 5: The Federal Government should support development of programs for increasing adult competencies in the use of informational technologies of all kinds.

Recommendation No. 6: Funding should be made available to public community learning resource centers, such as public libraries, for acquisition of hardware and software for use by the public.

Recommendation No. 7: An increasing amount of the $14 billion currently spent for adult education should be redirected to development and use of new technologies in order to achieve objectives in the adult education arena.

Second, a part of that recommendation, we believe increasing amounts of information technology and telecommunications expenditures should be directed toward adult education.

Recommendation No. 8: Current Government-supported delivery systems for informational and educational purposes, and we cite as one example the extension service, should be encouraged to make more uses of new technologies.

Recommendation No. 9: Preferential telecommunication rates should be established for educational purposes.

Recommendation No. 10: Stated more eloquently by Mr. Becker who might have been listening in on our discussions as well—copyright considerations should encourage widespread dissemination of educational materials.

Those are our recommendations, and we have other comments we will be happy to submit for the record.

I thank you. [Applause.]

Mr. BROWN. Thank you very much, Mr. Wall.

Any questions of Dr. Wall?

[No response.]

Mr. BROWN. Our last discussion group on the Development of Information Technology was chaired by Dr. Richard Ballard, manager of the Educational Program Information Center, Apple Educational Foundation.

DEVELOPMENT OF INFORMATION TECHNOLOGY: PRESENTED BY DR. RICHARD BALLARD, MANAGER, EDUCATIONAL PROGRAM INFORMATION CENTER, APPLE EDUCATION FOUNDATION

Dr. BALLARD. Thank you, Congressman Brown.

Most of the groups that have talked so far have represented users of instructional technology. Our own group was very much a group of people with interest and involvement in developing materials.

Our charge was to develop issues and recommendations on the development of instructional technology. If we had met 10 years ago, when I first started, the issues at that time would have been hardware. There was a lot of concern for the equipment. Projects that were starting then, PLATO projects and the TICCIT project and many of the others, were very strongly preoccupied with hardware. Today we have low-cost video units, we have microcomputers in great numbers, and it's fairly simple to see the rather exciting things that will come of putting the two together.

So there is less of a concern for presenting a vision of the kind of hardware we ought to have, and much more concern in this coming decade for the materials that are going to be developed, what they are going to be like, how they are going to happen.

The 1980's, we think, are going to be a decade of development. Hardware will still be very important, but it will probably just stir and confuse things, with each new capability in this long list of inventions that we can see coming along the line.

How will this development take place in the 1980's? Right now we are just starting, and it is not at all clear. Many people are now involved in development when before there were only a few who had access to equipment. Those who have long histories of developing programs and a lot of experience and skills are rather widely scattered and diluted now. The center stage in this process has shifted very fast. In the 1960's and 1970's, the projects of importance were very few, they were Federally funded, and they were run by people with academic backgrounds.

Today private investments in this field are just beginning to explode, and their dimensions in dollars and in people in multiple centers of production are clearly going to be huge. For the first time the private investors can see real markets of tens of thousands and hundreds of thousands of units, and they are attracted to those markets, and we are going to see investments flood in in areas where there are markets.

Our own group was perhaps the largest of the discussion groups, indicating the interest that people have in development at this time, and it represented educators and it also represented business people, people in training and in a lot of areas. That was very different from the kinds of conferences held in the past. There were a lot of representatives from corporations. Some of them are new, some of them have quite a bit of experience. Some of them are tinkering at the outside of this field, and others have very substantial commitments and powers within their organizations. All of them are making substantial career commitments—all of them are taking risks in getting involved in development at this early stage.

So we are just starting on development, and this is now a good time to look at public issues and private solutions. People are going out and betting that they know how to solve some of these problems and trying to do it. Individuals and companies are taking risks, investment risks, and if these people survive the 1980s, they will have found new solutions to a lot of new problems. They will have founded an important new industry, and as individuals they will have discovered a great time to be alive.

Now to those taking risks right now, there are some very important issues, and they are emotional issues like protection. They are risking their genius and their life's work and millions of dollars of investors' money, and they want some protection. They want copyrights and patents to really mean something. They are producing a new kind of property, an intellectual property, and in this coming age of information it is going to be one of this country's greatest resources. So our ability to protect and manage this resource, I think, is vital to our own country's future.

There are other issues. This courseware they are developing is extremely valuable, and more than any other medium, books or lectures, there is ample proof in the literature that it is effective, but it does take investment, there is front-end money involved in this, and we realize that Congress has less money to spend in this area rather than more. So we are not going to propose that Congress get into this in a big way, but we are asking them to fix the problems and to do some things that will trigger self-sustaining efforts by other people.

One of these things is royalty restrictions. Right now it is almost impossible for Government-sponsored projects to attain any size and to cooperate in any way with industry or to get out products, because of the royalty restrictions. People who are involved in these things know that as soon as there is a mention of royalty, then the project just can't seem to get anywhere.

We would like Congress to pick out certain project areas and funding areas, where it's fairly clear from the small markets and the importance of the projects that no one is going to get rich, and we would like them to remove all restrictions on the author's future collection of royalties. Those of us who are involved in development know that it is going to be virtually impossible to get rich in education, but we are committed anyway.

We think that in order to see these programs improve over time, the authors are going to have to have some incentive to go back and rework their projects, and not face a situation where all future proceeds are already committed to some big pot somewhere, and where there is absolutely no incentive to go on and make the work better.

We think there are places where Congress can stimulate the market with fairly small expenditures, and expenditures that would be only of a limited duration. We think that in just providing equipment, technological equipment like computers and video units, and in promoting awareness of programs among people who would be buyers—schoolteachers and administrators—in some ways, it doesn't really matter exactly how this is done. This is because in a number of areas—primary education is an example—right now I would say the penetration of that market is about 1 or 2 percent with this technology, and it takes only a little bit to get it up around ten percent, and about there it will be a self-sustaining market. Publishers and other people will be attracted to it and will provide materials.

Another thing Congress can do, and has done in the past, which seems rather easy to do, is to assign some percentages. We think they should, in any new funding of education, pick out a percentage to be spent on projects of advanced technology. If they're bold, we would like them to take another percentage—that would be to tax the media. Put a tax on tapes and computers and those types of things. Not a big tax—a tiny, tiny tax—but one that would yield, as this market and this field grows, an increasing income. Later on we think that we would start to have some of the money pots for doing the development of things that again would not be commercial, but would increase the excellence of the programs that are available. We think there is a chance now, by being bold, to secure those funds for the future.

One of the biggest issues today is the size of the development projects going on. Right now if you look around in video or in computers, you will find a lot of small programs, and they are not really very helpful. They are small programs because they are being developed by small projects, with small grants. Of course the issues are small, and that is why we think there are such small grants being given out. We would like to see them take the same money—not more money, the same money—and take at least part of it to divide up into some large projects, projects that can achieve curricular importance, that will put out enough in the way of materials that they will go into the classroom and have real impact. If you look at the large curricular packages that are available today, almost all of them in the math area, for instance, on microcomputers, came from Pat Suppes' projects more than a decade ago.

So we are asking—put some money in bigger pots and take some risks right now. There are other small things to be done. There is a lot of talk and great potential in putting Government expenditures on a cooperating basis with industrial efforts and with training corporations and others.

Why doesn't this happen? Invariably, when anybody tries to make a proposal and put together a program, a plan for cooperation in sharing resources and profits, there just aren't the regulations and the contractual methods for doing this. This whole thing snags on the fact that there isn't something written to allow this, so we think that a great deal would come out of looking very closely at some regulations and creating, in law and in policy, some things that would make this happen.

Another thing is that the Government is both a large purchaser of instructional technology and a source of grants that make other people purchasers. We would like them to put language in those grants and in their purchasing that would keep people who are excited about this field buying things just out of that excitement. As buyers, we would like to see requirements put upon manufacturers that they not only provide some minimal amounts of software, but they provide lists of software suppliers to their hardware, and that they provide materials and actually train the teachers and end users in this. Those things could be made into purchase packages in military uses, in training areas, and in education.

There is a need for authors now. There is enormous growth in this field and virtually no trained authors. We see need for fellowships that would bring academics into publishing and manufacturing situations, and take programmers and people out of the industries and into the schools. These kinds of exchange efforts would have a big impact on improving the training of authors.

There are other people taking risks right now, consumers are taking risks, and we think there need to be some centers for distributing information in understandable forms, to compare equipment in terms that are meaningful to school administrators. We need information that lists software, and tells you where it is available. It is important to have information on product performance, particularly as software comes in from a great many different manufacturers and becomes listed. We would like to see product performance evaluated, not so much in the way of standards but in the way of certification that the statements people are making are true. Is the cost of performance what the manufacturer claims it to me? We would like to see some efforts to encourage manufacturers to broaden their assumptions about who is going to use their equipment, being able to provide big keys that the elderly and people in special education are going to need.

There are some markets that publishers are never going to be attracted to. A lot of the investment has gone into the college market. But if you look at the numbers, and if you look at some of the specialty areas, you find that they will probably never be markets that will be attractive. There may be things developed there, but if they want in this early stage to see some substantial development, in science, for example, or in vocational areas, then the Government has got to plan a future of sustained support.

There are many other things: Learning model research—right now manufacturers and authors are going out and putting the stuff together by the seats of their pants, and you will see more and more of that. We need guidance to tell what paradigms and strategies are effective for this medium and most likely to produce learning.

During the 1960's and 1970's Congress was really responsible through its funding for the push in this area. Today this development is rolling along. Right now we are asking for help from Congress to steer this, and if we can't get that help then we think it would be wise for Congress to at least get out of the way.

Thank you. [Applause.]

Mr. **Brown**. Thank you. We will try to get out.

The Congress is working in some of the areas that have been mentioned by several of the speakers such as: copyrights, patents, improvement of the public/private cooperation mechanisms. All of these represent ongoing, and very active issues in the Congress now. The input of this meeting will be helpful.

Are there any questions of Dr. Ballard?

The gentleman over there.

Mr. **Komoski**. Ken Komoski, EPIE Institute. I would like to make one point regarding certification on the part of software producers that they have done what they say they have done.

I would like to point out that in 1971 I testified before this committee regarding the need for this, and subsequently working in your State, sir, with legislation requiring this in the State of California.

Subsequent to that, working with the State senate in Florida, there was additional legislation passed in that regard. The State education agencies have done nothing with this legislation. There is a mechanism now and all we need to do is to have it applied, and what you are suggesting needs to be done could be done.

Mr. **Brown**. Thank you for that comment.

Do you have any response, Dr. Ballard?

Dr. **Ballard**. Well, I think every effort that could be made in this regard should be made As I pointed out, things are coming from all over, and people are making very bold statements about their value. I have been on the other side of this question too with a manufacturer who produced quite a bit of audio tutorial material. It so happened that one of his programs was taken under evaluation by a student at the University of Southern California, who wrote his doctoral thesis on the value of this program. The manufacturer was delighted to have the results, publicized them widely, and the program sold very well.

His idea next was, where can I get these programs tested by somebody else so that I can say that about all my programs. What he was looking for was someone to put together a validation procedure whose results would be accepted as having some value by educators. All he wanted was them to tell him how much it would cost per program to put these things through it. He thought it was probably cost effective to do that. We do need not just a law, but organizations coming forward with methodologies for evaluating these programs so manufacturers can test them. I would think they would pay for them.

Mr. **Brown**. Any other questions?

[No response.]

Mr. **Brown**. Let me interject another comment then, if I may. The importance of this subject needs to be emphasized over and over again—I am talking about the total of information technology here, and this comment about standards and methods of evaluation leads me to think about the global economic importance of what is going on here. What we are talking about is something that is going to penetrate the entire global economy.

One of the things that we need to be concerned about is the United States market position. We are not going to be marketing our own particular brand of software or courseware, for example, to meet the information needs of the rest of the world. They will want to produce their own that is compatible with their culture and their needs. What we are going to sell to them probably is some hardware and maybe some of the hardware types of software.

When it comes to most of the software things, we are going to be selling them procedures and methods of creating what will be suitable for their situation and their methods of evaluation. We really need to step back in our society as we go through this period and not only do it, and test it, but analyze how we did it, how we tested it, and how that can be applied to markets in other parts of the world, because that is what they are going to want in order to go through the transition a lot faster than we have gone through it.

What always strikes me as an example of what is happening here is the fact that the first real deal we made with the mainland Chinese was for information technology. They want a satellite system and several thousand ground stations. They want us to supply them and they will figure out how to use them to avoid putting in a hard-wired communication system. They will skip the business of wiring China and go directly to satellites. How do we take advantage of their needs in a way that meets both of our requirements? That it helps both of us, is the point that I worry about a great deal because in the long run that's what we will have to do.

Any more questions?

All right, we have one additional wrapup speaker, a man who in my opinion is probably the best informed person in this field of any I have worked with, and that is Mr. Bob Chartrand of the Congressional Research Service, Library of Congress. For one reason or another he has been involved in this subject matter for a long number of years, and I guess it has honed him to a fine edge to have to meet all of the deficiencies of the Members of Congress in this area. He has developed a great competence in this field.

SUMMARY: PRESENTED BY ROBERT CHARTRAND, SENIOR SPECIALIST IN INFORMATION, POLICY AND TECHNOLOGY, CONGRESSIONAL RESEARCH SERVICE, LIBRARY OF CONGRESS

Mr. Chartrand. Thank you for the introduction, Chairman Brown.

My remarks are brief, but perhaps will be useful in touching on one or two points that I think all of you here will find relevant.

In establishing a useful context for this seminar on information technology in education, Chairman Brown offered a twofold objective: To enhance the awareness of the Congress, the executive branch, and the private and public sectors of (1) the potential education benefits of new information and telecommunications technologies, and (2) the possible social and economic impacts resulting from the widespread use of these technologies in the educational process.

As I look back over the dozen or more years I have spent on the Hill, I recalled that it was precisely a decade ago that the then House Committee on Science and Astronautics chose to explore through a series of special papers and discussions, the topic they called the Management of Information and Knowledge, and I would like to think there are a few of us in this room that recall the splendid booklet that came out as a result of that milestone series of meetings.

Among the several dimensions of that topic was the role of information technology, and germane to our present seminar, coming 10 years later, was the emphasis by McGeorge Bundy, at that time serving as president of the Ford Foundation, on understanding the "boundaries" of technology supported systems, including both the benefits and limitations of the new tools and techniques. It seems to me the applicability of his comments about the advantages of using computers to assimilate and integrate selected data so that the user can most fully utilize the products, and his reminder that the "direct relationship between the quality of raw data elements or input and the value of knowledge outputs" must always be understood. I think these observations still merit our attention.

This seminar we just completed over the last 2 days has been possible because it is comprised of you, the seasoned professionals—those who function as conceptualists, as catalysts between the subject areas and the technology which can process and display the desired information, the teachers, the technological innovators, and what we now call the gatekeepers of information. It is because of your interest and involvement that these working sections are producing the kinds of information which will assist the two sponsoring subcommittees through an exposition of: First of all, the key issues related to maximizing the positive impact of information technology in the educational milieu; and second, those identifiable initiatives which Congress, the Federal executive branch, and the private sector may undertake to enhance understanding and support of this vital area.

These hearings and workshop sections are seen as a beginning—a beginning which will enable cognizant congressional groups to evolve new perceptions and legislative approaches that can result in improved planning and programs. Needless to say, your sustained support is extremely important as the Subcommittee on Science, Research and Technology and the Subcommittee on Select Education continue to address the several facets of this focal area: Economic, technical, cultural, and legislative.

I ran across a quotation at home from Thomas Jefferson which touched on what we face today, and what we should keep in mind. In a letter to a friend of his, observed that: "Laws and institutions must go hand in hand with the progress of the human mind. As that becomes more developed, more enlightened, as new discoveries are made, new truths disclosed, and manners and opinions change with the change of circumstances, institutions must advance also and keep pace with the times."

The spirit of this collection of dedicated individuals here before me, responding promptly within the democratic process, is a remarkable reflection of the philosophy embodied in the ancient proverb which said that "where there is no vision, the people perish."

I do not think it would be amiss if I express, on behalf of all of us here, our appreciation to George Brown, for his leadership and his genuine, sustained support.

Thank you very much. [Applause.]

Mr. Brown. That was very kind of you, Bob, and I appreciate it. We are just about to bring this very beneficial and enjoyable meeting to an end. I want to take care of a few small details which help to make this an official record, and to offer a few words of thanks myself before I ask Dr. Ostenso to give the benediction.

First of all, without objection of any other Member of Congress—and I know there will be none—the full report of all the discussion groups will be included in the hearing record.

Second, likewise to be included will be a list of all the workshop participants who developed these reports.

Third, the prepublication prepared by the Congressional Research Service on Information Technology in Education will be made a part of the hearing record, and the brochure prepared as a guide to the technology demonstrations.

I say that because if we get them in the record we can print them all, and that will be included in the final document that we hope will be widely distributed.

Now let me express my very deep appreciation to all of the following, and I apologize to any that I may have missed.

First, as you all know, the Library of Congress, through the Congressional Research Service, made a tremendous contribution to the preparation and conduct of this meeting. Bob Chartrand was the leader of this group, he was assisted by Jerry Borrell, and they were involved in every stage from the early planning on to the end.

Jean-Paul Emard, who also is at the Congressional Research Service was of major help in developing the seminar materials and managing the demonstrations which were set up in the annex, and Jim Price and his staff have been doing the video brief, which is that machine you see taking all of the pictures.

I might say incidentally an edited version of this will probably be made available to the public and will be played on our own magic system here in Congress. We are all wired into a House Information System and each office has a television monitor in it. We will in this way be able to distribute the results of this seminar to the Members and staff in congressional offices.

I also want to thank the planning team. I don't want to name them all, but there were representatives from the Government Operations Committee, the House Administration Committee, and plus, of course, the two committees that were actually conducting this, as well as the National Science Foundation, Office of Education, National Institute of Education, ARPA, OTA, and other organizations too numerous to mention.

I want to give special thanks to the House Administration Committee, and especially Ken Showalter, for hosting the demonstrations. I, of course, want to thank all of the very distinguished witnesses who appeared, and gave us the benefit of their testimony, and the chairpersons and recorders of each of the discussion groups.

That is a good indication that practically nothing good gets done around here unless there are a lot of people involved, and probably the least is the Congressman who presides over them, which is me.

I will ask Grace to say the final word. She did most of the work.

Dr. OSTENSO. I would like to say on behalf of the cosponsoring Subcommittee staffs on Select Education and Science, Research and Technology, and the total planning team, that we thank everyone who participated in this "extravaganza." We are particularly grateful for the quality of your recommendations, the value of the output, and for the generosity of your personal time and resources. We too would like to thank Mr. Brown for his guidance, motivation, and commitment which made this information technology in education seminar possible.

Mr. BROWN. We are adjourned.

[Whereupon, at 3:15 p.m. the hearing was adjourned.]

APPENDIX

INFORMATION TECHNOLOGY IN EDUCATION:

A JOINT HEARING AND WORKSHOP

Sponsored by

The Subcommittee on Science, Research and Technology
Committee on Science and Technology
U.S. House of Representatives

and

The Subcommittee on Select Education
Committee on Education and Labor
U.S. House of Representatives

April 2-3, 1980

At the request of Rep. George E. Brown, Jr., Chairman of the Subcommittee on Science, Research and Technology of the Committee on Science and Technology, and Rep. Paul Simon, Chairman of the Subcommittee on Select Education of the Committee on Education and Labor, the Congressional Research Service assisted in developing this review of information technology in education and future issues and policy implications of the use of these technologies in the educational process.

The membership of the Subcommittee on Science, Research and Technology is:

George E. Brown, Jr., California, Chairman

James H. Scheuer, New York
Donald J. Pease, Ohio
Tom Harkin, Iowa
Allen E. Ertel, Pennsylvania
Kent Hance, Texas
Wes Watkins, Oklahoma
Don Fuqua, Florida (ex officio)

Harold C. Hollenbeck, New Jersey
Robert W. Davis, Michigan
Donald Lawrence Ritter, Pennsylvania
John W. Wydler, New York (ex officio)

The membership of the Subcommittee on Select Education is:

Paul Simon, Illinois, Chairman

John Brademas, Indiana
Edward P. Beard, Rhode Island
George Miller, California
Augustus F. Hawkins, California
Mario Biaggi, New York
Edward J. Stack, Florida
Carl D. Perkins, Kentucky (ex officio)

Ken Kramer, Colorado
E. Thomas Coleman, Missouri
Arlen Erdahl, Minnesota
John M. Ashbrook, Ohio (ex officio)

The Subcommittees wish to acknowledge the support provided in connection with this workshop publication and the planning and coordination of the entire seminar by professional staff members of the Congressional Research Service: Robert L. Chartrand, Senior Specialist in Information Policy and Technology; and Jean-Paul Emard, Analyst in Information Sciences, Science Policy Research Division. These activities were performed in close cooperation with: Allen Cissell, Deputy Director, Subcommittee on Select Education; Grace L. Ostenso, Science Consultant, Subcommittee on Science, Research and Technology; and Robert Smythe, Science Fellow, Office of Rep. George E. Brown, Jr.

PUBLICATION OUTLINE

Prologue

I. Introduction

II. Background to Information Technology in Education
  A. Chronology of Selected Events and Legislation
  B. Overview of Present-day Applications, Stakeholders, and Goals
    1. Existing Applications
    2. Stakeholder Roles
    3. Achievement of National Goals
  C. Perspectives on Information Technology in Education

III. Workshop Issues, Themes, and Questions
  A. The Broad Issues of Information Technology in Education
  B. The Workshop Issue Clusters
    1. Elementary and Secondary Education
    2. Post-Secondary Education
    3. Adult Education
    4. Special Education
    5. Development of Information Technology
    6. Public Planning for Education in the "Information Society"
  C. Potential Methods of Fostering Legislative Initiatives

IV. Selected References
  A. Government Publications
  B. Books and Reports
  C. Periodical Articles

PROLOGUE

The ability to rapidly store, retrieve, and transmit enormous quantities of information is a fundamental technological reality of today. The use of information technologies to facilitate research, to organize and access data for knowledgeable decisionmaking, and to perform complex administrative and managerial tasks now is taken for granted. At the same time, the rapid maturation of these technologies and the convergence of telecommunications and information technology present policymakers with new and difficult challenges. If public policies are to be responsive to the needs of our "Information Society", we must develop mechanisms and institutions with the flexibility to adapt to technological change and to cope, in a humane and equitable way, with the increasingly interdisciplinary nature of new knowledge.

Improving the planning, management, and evaluation of scientific and technical information activities has been a major focus of the Science, Research and Technology Subcommittee. The use of information technology in education is an important part of this activity, both as a means of enhancing the quality of instruction and in increasing the ability of citizens to use this valuable technological tool. We welcome the opportunity to join with the Select Education Subcommittee in exploring this vital intersection of education with information science and technology.

The workshop participants' recommendations in this area will benefit the entire Congress as we move toward the development and implementation of a coherent national policy for the management of our information resources.

George E. Brown Jr.

George E. Brown, Jr., Chairman
Subcommittee on Science, Research and Technology

The Subcommittee on Select Education is pleased to join with the Subcommittee on Science, Research and Technology in sponsoring a workshop on information technology in education. One could refer to this workshop as a "foresight" hearing, in contrast to the usual Congressional practice of reviewing past programs and current program problems. It is important, I believe, that the Congress concentrate some of its attention on the likely impact of information technology on teaching and learning and on our educational institutions.

The new technologies, properly utilized, will give our society new capacities to understand itself and to understand other cultures. Inevitably, we will become more sensitive to the interdependent nature of this "spaceship earth" we inhabit. Inevitably, information will become less centralized, making education less institutionalized and more democratic. Inevitably, considerable change will occur in the organization and governance of our educational institutions.

The Subcommittee on Select Education and the Subcommittee on Science, Research and Technology eagerly look forward to the participants' insights and recommendations in this important area.

Paul Simon

Paul Simon, Chairman
Subcommittee on Select Education

I. INTRODUCTION

The legacy of the past decade — an enhanced educational, economic, and social standard of living — is based in large part on the advancement and application of information and telecommunications technologies, and on the convergence of these technologies. Through continued developments and refinements in the miniaturization of electronic components and circuitry, the seventies witnessed the continued evolution of improved cable communications, satellites, computers, and sophisticated information storage, retrieval, and delivery systems responsive to the needs of nearly every facet of our society. Government, banking and finance, manufacturing, business and office practices, medicine, law enforcement, and the home environment all were touched by the seeming wizardry of such technologies. With more scientific, technical, and industrial innovations in the offing for information processing and telecommunications systems, the decade of the eighties promises to bring into being Daniel Bell's "post-industrial society" and the much-publicized "information age."

The continuing innovative applications of information and telecommunications technologies may impact strongly upon one area of endeavor long awaiting the promised benefits of automation and space-age communications: the American educational system. Although the advent of educational television and promising beginnings in computer-managed and computer-assisted instruction generated talk of education's "fourth revolution", the expectations of this revolution were never fully realized at any educational level. Now, however, cable and interactive television, videodiscs, satellite broadcasting, distributed data processing, and microcomputers — the basics of the "new" information technologies — give renewed hope that these advanced technologies may yet become an integral part of the Nation's scientific and educational environment.

The objectives of the "Information Technology in Education" Seminar are to enhance public awareness of (1) the potential educational benefits of new information and telecommunications technologies, and (2) the possible social and economic impacts resulting from the widespread use of these technologies in the educational process. This booklet provides a framework for accomplishing the seminar objectives by highlighting (1) selected past, present, and future uses of information technology in education; (2) salient issues encountered or engendered by today's educational technologies; and (3) possible approaches available to Congress for guiding and directing the use and adaptation of new information technologies in the educational process.

II. BACKGROUND TO INFORMATION TECHNOLOGY IN EDUCATION

A. Chronology of Selected Events and Legislation

To place some perspective on where educational technology is today and what its future may hold, a brief review may prove beneficial. Since educational technology -- especially within the realms of programmed instruction, teaching machines, radio, and television -- has been evolving continually for many years, the following is a selected sampling of significant events, pertinent legislation, and milestone reports that have influenced the utilization of new technologies in education during the past quarter century.

1956	Schools in Hagerstown, Maryland begin to receive the first cable transmissions of instructional television.
1958	National Defense Education Act (P.L. 85-864) [as amended by P.L. 88-210] and the Instructional Media for Handicapped Children Act (P.L. 85-905) [as amended by P.L. 89-258, as amended by P.L. 90-247, title I] are signed into effect.
1960	The New England Educational Data Systems (NEEDS) program begins on a modest basis as the Data Processing Project of the New England School Development Council.
	Plato I experiments in computer-assisted drill-and-practice and tutorial programs begin at the University of Illinois.
1962	After a joint convention of State educational data processing specialists and members of the California Educational Research Association in 1961, the California Educational Data Processing Association (CEDPA) is founded.
	A small group of educators from State Departments of Education, universities, and large school systems establish the Association of Educational Data Systems (AEDS).
1963	The Council of Chief State School Officers establishes a Commission on Educational Data Systems (CEDS) to conduct studies, formulate recommendations, and plan for development on behalf of all State Departments of Education.
	Mental Retardation Facilities and Community Mental Health Centers Construction Act (P.L. 88-164) [as amended by P.L. 89-105, as amended by P.L. 90-247], the Higher Education Facilities Act (P.L. 88-204) [as amended by P.L. 90-575, title VI], and the Vocational Education Act (P.L. 88-210) [as amended by P.L. 90-576] are passed.
	The Institute for Mathematical Studies in the Social Sciences at Stanford University begins a laboratory program of research and development on computer-based instruction that receives funding from NSF and the Carnegie Corporation.

1965	The White House Conference on Education is held and its final report, *A Milestone for Educational Process*, is published.
	Elementary and Secondary Education Act (P.L. 89-10) [as amended by P.L. 90-247, as amended by P.L. 91-230] and the Higher Education Act (P.L. 89-329) [as amended by P.L. 90-35] are signed into law.
	The Educational Resources Information Center (ERIC) system begins with its first production and dissemination of the *Catalog of Selected Documents on the Disadvantaged*.
1966	The Joint Economic Committee holds hearings on "Technology in Education" followed by the publication of the committee print, *Automation and Technology in Education*.
	Library Services and Construction Act (P.L. 89-511) and the Adult Education Act (P.L. 89-750) are enacted.
1967	The President's Science Advisory Committee issues its report on computers in higher education.
	Model Secondary School for the Deaf, utilizing all of the latest technologies for educational and other purposes, is established by P.L. 89-694 on the campus of Gallaudet College.
1968	President Johnson appoints a Commission on Instructional Technology.
	Association for Development of Computer-based Instructional Systems (ADCIS) is founded in order to advance and promote computer-assisted or managed instruction at secondary and higher education levels.
	Sesame Street (and The Electric Company in 1972) begins to receive funding from the Office of Education under the Cooperative Research Act (P.L. 83-351).
1969	The first Conference on Computers in Undergraduate Curricula is held at the University of Iowa.
	The U.S. Department of Defense Advanced Research Projects Agency (ARPA) begins to interconnect four western universities into a computer networking configuration called ARPANET.
	National Center for Media and Materials for the Handicapped Act (P.L. 91-61) authorizes the creation of a media and materials center for varied technologies and applications for the handicapped.
1970	The House Subcommittee on Select Education holds hearings on the Educational Technology Act of 1969.

1970 John Hamblen, under NSF contract, produces the first Inventory of Computers in U.S. Higher Education, 1966-1967 that provides a comprehensive statistical base of usage, types of use, and expenditures on computers in higher education.

National Commission on Libraries and Information Science is established by P.L. 91-345.

The final report of the Commission on Instructional Technology, To Improve Learning, is issued as a House Committee on Education and Labor committee print.

Amsterdam is the site of the 1st World Conference on Computer Education.

1971 The House Subcommittee on Select Education receives testimony on the establishment of a National Institute of Education.

A publication of selected references on new technologies in education is issued by the House Committee on Science and Astronautics.

National Science Foundation grants funding for the development of two computer-assisted teaching systems, Plato IV of the University of Illinois and TICCIT of the MITRE Corporation.

1972 The Carnegie Commission on Higher Education releases two major studies, The Fourth Revolution: Instructional Technology in Higher Education and The Emerging Technology: Instructional Uses of the Computer in Higher Education (in conjunction with The Rand Corporation).

National Institute of Education is established as a quasi-governmental body and a National Center for Educational Technology is established in the Office of Education.

Hearings on educational technology are held by the House Subcommittee on Select Education.

The Emergency School Aid Act (P.L. 92-318, title VII) authorizes the development and use of new curricula and instructional methods, including the acquisition of any instructional materials and technologies, for use by all children regardless of race, color, or economic standing.

1973 The Ford Foundation publishes An Inquiry into the Uses of Instructional Technology.

The MITRE Corporation publishes a study on its Reston, Virginia experiment involving the technical and economic considerations attendant on the home delivery of instructional and other socially-related services via interactive television.

Issues and public policies in educational technology are discussed in the National Academy of Engineering's To Realize the Promise.

1973 Demonstration of Plato is a featured presentation at hearings on Federal information systems, plans, and the development of advanced information technologies held by the Subcommittee on Foreign Operations and Government Information.

1974 Under the Education Amendments of 1974 (P.L. 93-380), (1) the Commissioner of the Office of Education is empowered to use, at his discretion, certain funds for educational television; and (2) the Office of Library and Learning Resources is created to administer all funding and oversight of those technologies used for instructional programs.

1975 *Computers and the Learning Process in Higher Education* is prepared for the Carnegie Commission on Higher Education.

Education for All Handicapped Children Act (P.L. 94-142) is passed.

1977 "Computers and the Learning Society" is the theme of the hearings and the subsequent committee print (1978) of the House Subcommittee on Domestic and International Scientific Planning, Analysis and Cooperation.

1978 Title II of the Education Amendments of 1978 (P.L. 95-561) stresses the need to utilize new technologies to improve and develop basic skills and Title XV grants assistance for children's educational television.

1979 The first National Educational Computing Conference is convened at the Univeristy of Iowa.

Final report on *Videoconferencing via Satellite: Opening Congress to the People* is published detailing certain educational uses of this conferencing technique.

American Federation of Information Processing Societies (AFIPS) convenes a panel to study the scientific and technical implications of information technology in education.

The House Subcommittee on Science, Research and Technology holds hearings on "Information and Communications Technologies Appropriate in Education (including H.R. 4326)".

The White House Conference on Library and Information Services is held in Washington, D.C.

House Subcommittee on Science, Research and Technology, the Senate Subcommittee on the Handicapped, and the Congressional Research Service jointly sponsor a three-day series of panel/workshops on the "Application of Technology to Handicapped Individuals" with a subsequent 1980 committee print.

B. Overview of Present-day Applications, Stakeholders, and Goals

1. Existing Applications

Technology in the classroom is not a new concept in the educational process. Books, blackboards, charts, maps, filmstrips, motion pictures, phonographs, tape recorders, and language laboratories all can be classified as instructional tools; and, for the most part, each has been widely accepted as a teaching enhancement. Newer forms of educational technology, and more specifically computers, have not fared as well in their acceptance:

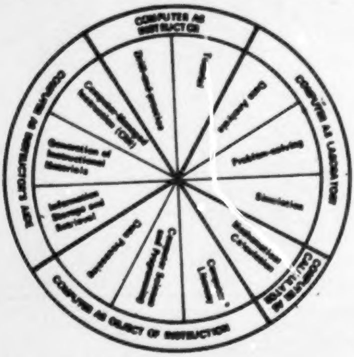
> The possibility that computers will be used in schools seems to turn otherwise reasonable men and women into implacable Luddites or doomsday zealots...The former think the latter are bloodless technicians. The latter find the former fearful reactionaries. 1/

Classifying anyone into these two diametrically opposed camps may be an oversimplification but it does illustrate the diversity of reactions to certain new information technologies in the instructional setting. Some of the negative reactions may be due to the previous failure of such technologies to achieve their full potentials in the educational arena. Although automated information and telecommunications systems seemed in the 1950s and 1960s to hold much promise, the difficulty of integrating man-machine techniques into established teaching methods and psychological resistance to change, coupled with expensive instructional programming and systems costs, kept the promise from being fulfilled.

During the past several years, however, new and improved methods of information delivery have helped bring educational instruction to a great many individuals and rekindled the spark of promise. Communications satellites have been used to transmit curricula and special programs to large urban areas and to such remote sites as Alaska, the Pacific Islands, and the Appalachians. Such systems also have been used for satellite conferences and meetings between educational groups, government representatives, and student bodies. Telecommunications networks have facilitated the sharing of resources, course work, and scientific and educational research at all levels of education. In a similar vein, "electronic blackboards" have linked instructors and off-site students without the need for costly travel. The development of videotapes and videodiscs may result in one-time investments for equipment capable of serving as high-volume, interactive information storage and retrieval sources of educational materials. Television, via broadcast or cable, continues to be a familiar medium for providing inexpensive mass dissemination of educational programs and learning experiences. The capabilities of interactive television systems for educational purposes also have been tested and put into operation in certain locales.

Of all the technologies now in use in the educational environment, the computer may have the greatest impact. Already, computer-assisted instruction is a recognized method of providing drill-and-practice and tutorial exercises. Moreover, the computer as a delivery system plays an important role in preparing today's students for the "Information Society" of tomorrow.

FIGURE I:
The Roles of the Computer in Education 2/


COMPUTER AS INSTRUCTOR
COMPUTER AS LABORATORY
COMPUTER AS CALCULATOR
COMPUTER AS OBJECT OF INSTRUCTION
Problem-solving
Simulation
Generation of Instructional Materials
Computer-Managed Instruction (CMI)

2. Stakeholder Roles

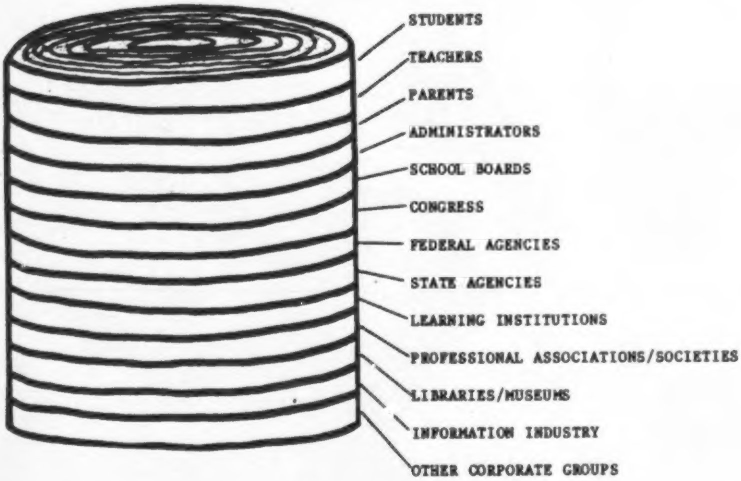
In assessing the current position of information technology in education, it is important to identify the main actors and the target audiences. More specifically:

(1) Who are the stakeholders in the development, use, and accountability of new educational technologies? and

(2) What different educational levels or settings are affected by these stakeholders?

In part, the first question may be answered by the following graphic:

FIGURE II:
Stakeholders in the Development, Use, and Accountability of Educational Technology


STUDENTS
TEACHERS
PARENTS
ADMINISTRATORS
SCHOOL BOARDS
CONGRESS
FEDERAL AGENCIES
STATE AGENCIES
LEARNING INSTITUTIONS
PROFESSIONAL ASSOCIATIONS/SOCIETIES
LIBRARIES/MUSEUMS
INFORMATION INDUSTRY
OTHER CORPORATE GROUPS

It is recognized too that this array of stakeholders has indentifiable involvement in varying educational environments including: elementary/secondary, vocational, post-secondary, graduate, special, professional, and lifelong learning.

3. Achievement of National Goals

The humane and effective use of any technology requires a clear view of its role in meeting public needs and enhancing the well-being of our Nation and of the world community. By augmenting educational resources and improving services, information technology promotes the advancement of learning and of research in all fields. This in turn furthers the broad goals shared by all stakeholders in the information technology enterprise: increasing economic productivity and improving the quality of life.

Since the business and professional worlds now depend on computer and information-based systems in meeting daily work requirements, progress towards these goals depends upon the achievement of "computer literacy" throughout our society. Our educational institutions and special training programs will make a significant contribution toward fulfilling these goals by playing a lead role in providing both conceptual and practical knowledge of information processing and transmission systems to all student groups.

C. Perspectives on Information Technology in Education

In 1972, the Carnegie Commission on Higher Education's "Fourth Revolution" report depicted the results of a study on the future availability and use of selected technologies in post-secondary educational facilities.

FIGURE III:
Projected Availability and Use of
Nine Educational Technologies

	Faculty predictions of availability	Technologists' predictions of routine use	Faculty predictions of routine use for undergraduates	Faculty predictions of routine use for graduates
Routine audiovisual technology	1972	1974	1975	1980
Programmed instruction	1975	1978	1982	2010
Routine computer-assisted instruction	1977	1978	1982	[illegible]
Computer simulation	1979	1979	1983	[illegible]
Advanced computer-assisted instruction	1984	1980	[illegible]	[illegible]
Computer-managed instruction	[illegible]	[illegible]	[illegible]	[illegible]
Remote classroom feedback	1974	1978	1984	[illegible]
Student-initiated access to audiovisual	1975	1979	1979	[illegible]
Computer-aided course design	[illegible]	[illegible]	[illegible]	[illegible]

This study indicated that only routine audiovisual technology and student-initiated access to audiovisual materials would be in use at the start of this decade. Sophisticated interactive, computer-based systems would not be routinely utilized until the 1990s or later.

While this and other educational technology reports of the late 1960s and early 1970s discussed many different innovations in state-of-the-art and near-future information and telecommunciations technologies, there is an absence of any critical review of the significant impact such technologies might have on the Nation's varied educational systems. Today, most information technologists agree that such telecommunications media as traditional coaxial cable and newer optical fibers — capable of bringing hundreds of different information resources into the school, office, and home — will become more readily available in the next 10 to 15 years. Closed and open circuit television programming will be standard viewing fare at most instructional sites. The broadcasting of special, narrowly-focused programs and information services directly to a given student's location will be made possible through direct satellite broadcasting. More exotic uses of satellites will include their linkage with holographic projection techniques to present "live", three-dimensional representations of people, places, and objects for classroom study.

A continued proliferation of automated information systems in the educational environment of the future appears inevitable. Students and teachers alike will come to rely on bibliographic and statistical data bases, micrographic storage and retrieval systems, and specialized interactive cable and videotext systems for data and information access. Other frequently used educational technologies will include such audio and audiovisual learning tools as interactive movies, videotapes, and videodiscs. More important, however, will be the significant impact of the microcomputer. Hand-held calculators will be commonplace in math and science centers. Low-cost personal microcomputers — either in stand-alone or distributed configurations — will not only permit information storage and retrieval, drill-and-practice, and tutorial lessons in the classroom, but will extend educational experiences into the home. In turn, extension of this experience may well foster greater individualized educational interest in school and work-related subjects and accentuate the growing trend towards lifelong learning.

III. WORKSHOP ISSUES, THEMES, AND QUESTIONS

A. The Broad Issues of Information Technology in Education

The effects of new information technologies on educational and social institutions -- when viewed within the context of the preceding narrative -- may yet be profound. In this world of increasing complexity, many difficult issues -- economic and social as well as cognitive and technological -- need to be addressed as information technologies become a more important influence on both the form and the content of educational processes.

The cognitive and technological questions center mainly on efforts to create information technology-based learning systems that allow students broad opportunities for initiative. These efforts require the development of new "knowledge bases" to provide a rich, machine-assisted learning environment and point toward an increasingly sophisticated interaction between cognitive sciences and educational technology.

Perhaps the most obvious economic issue is the cost-effectiveness of learning systems based on the use of information technology. There is no doubt that the high development and sustaining costs of some of these new approaches caused some initial disillusionment in the educational community. Although hardware costs continue to decline dramatically, educational considerations have not been a major force in hardware design, and the development costs of educational software and "courseware" remain high. Evaluation of comparative costs and effectiveness for different technology-based systems may become even more difficult as advanced systems evolve with services and products ill-suited to traditional measurement techniques.

At least two other important economic issues must be considered. One is the effect of information technology on the utilization of educational personnel, including the costs of appropriate training and the updating of skills. The second is the value of information technology in school management and administration; the flexibility of today's equipment offers the possibility of designing systems capable of performing concurrently both instructional and administrative tasks. Furthermore, the significance of such qualitative and quantitative trade-offs need to be viewed within the context of a more fundamental economic issue -- the long-term effect on our national productivity of the widespread use of (or failure to use) information technology in education.

The penetration of information technologies into the school, workplace, and home raises some vexing social questions for a democratic society. Proponents of educational technology have praised its ability to equalize opportunity by delivering quality programs and services to remote areas or to disadvantaged sectors of the population. Taking advantage of this technology, however, depends not only on the availability of hardware but also on the presence, in the school, workplace, or home, of people trained to accept and use it for educational ends. Promoting equality in this dimension is a major challenge.

The proliferation of home-based information technology, in particular, may have important consequences for the future of educational institutions. The effect may be positive, at least in part, in generating pressure for wider use of information technologies in schools and colleges. A longer-term consideration is the increasing ability of information technologies to meet educational needs in the workplace and home; this could have a profound impact on traditional educational arrangements at all levels. This prospect in turn raises some troubling questions about the possible effects of more decentralized learning systems on individual social development and interpersonal relations.

A related set of concerns about information technology centers on the preservation of privacy and individual liberties. This consideration arises both from the growing vulnerability of computerized data to unauthorized access and the fear that technology-based education will emphasize facts over concepts and principles and could be used to propagandize and condition tastes and beliefs.

Finally, a number of institutional issues concerning the involvement of government at all levels will have to be confronted if real progress is to be made. First, the appropriate role of the Federal Government in information technology research and development merits reevaluation in view of changing conditions and technologies. Second, the role of Federal and State Governments in training educational personnel to use the new technologies warrants reexamination. Third, attention should be directed to the Federal Government's role in monitoring current efforts in the development, application, and dissemination of information technology in education. Fourth, the development of altenative approaches to improved cooperation between the various Federal agencies involved in information technology development and education deserves reassessment. Fifth, the need for standardizing the components of information technology and the requirement for shaping that technology to meet educational objectives should be explored. The lessons learned from these efforts could be useful in undertaking the important tasks of building a coordinated national policy for the development and use of our national information resources.

B. The Workshop Issue Clusters

The preceding issues form the backdrop for the more detailed and focused deliberations of the six workshop discussion groups. Groups I-IV identify target audiences; Groups V and VI deal with public policy issues in technology development and implementation, and cut across all user categories. Some of the major issues in these areas are listed below.

1. Group I - Elementary and Secondary Education

o What are the benefits and limitations of using specific information technologies in developing and upgrading skills?

o Will the ability of some families to purchase information technologies for their homes have serious impacts on information equity? If so, should schools compensate, and how?

o What are the likely effects of individualized technology-supported instruction on the socialization of children?

o What changes in teachers' roles might result from the introduction of information technology into the classroom? What effects will these changes have on teacher productivity, morale, and the need for special training?

o Is information technology likely to produce significant changes in employment patterns for teachers?

o What is the role of demonstration projects in expanding the awareness of the uses of information technology in education?

o What mechanisms are possible or desirable to ensure that the use of technology-aided instruction does not unduly condition tastes and beliefs?

2. Group II - Post-Secondary Education

o What role should information technology play in "remedial" education?

o What measures might encourage a faculty to develop and use information technology-based instructional materials?

o What is the appropriate level of "computer literacy" for college students? Is there a need for a "model curriculum" in this area?

o What activities could be undertaken to encourage better training for prospective teachers in the use of information technology?

Group II (cont.)

o Is the current availability of trained specialists in information technology adequate? Is there a need for more interdisciplinary training of information professionals?

o What possibilities exist for the sharing and exchange of equipment, programs, or data bases with other educational institutions? with industry?

o Is Federal support for the purchase and maintenance of information technology sufficiently consistent to provide an adequate basis for long-term decisions on systems design and acquisition?

3. Group III — Adult Education

o What are the potential economic benefits to be derived from the use of information technology for instruction in the workplace? What are the limitations?

o What role can information technology play in continuing education programs for professionals?

o What possibilities do information technologies offer for training unskilled or functionally illiterate adults?

o What are the social implications of home-based adult education programs now and in the future?

o What problems do information technology-based systems face in gaining acceptance by the adult public?

o Should wider use of information technology in extension services (e.g. agriculture, energy, etc.) be encouraged? If so, how?

o How can information technology be used to augment the role of museums and libraries in adult education?

4. Group IV - Special Education

o What are the particular technological needs of the different target audiences within the special education field?

o What incentives would effectively encourage the development of technologies with special features for the handicapped or the learning disabled?

o What marketing strategies are appropriate for information technologies aimed at special education? Should the Federal Government play a role in market aggregation?

Group IV (cont.)

- o What are the benefits and limitations of home-based education to differing special education groups?
- o What consequences is information technology likely to have for "mainstreaming" policies?
- o How might information technology be used in teaching motor skills to the handicapped?
- o How might information technology be used in educating gifted children?

5. Group V - Development of Information Technology

- o What role should the Federal Government play in research and development in the field of information technology?
- o What are the possibilities for industry-government cooperation in research and development?
- o Is there a need for more support of applications of cognitive psychology research to computer-based learning?
- o What effects do current patent and copyright policies have on the development of software and courseware? Do these policies favor the use of some information technologies over others?
- o Should demonstration projects in information technology be developed and displayed? Should regional centers be established for this purpose?
- o What is the appropriate level and nature of involvement of the Federal Government in the dissemination of program/grant information, research results, and courseware?
- o Is current telecommunications regulation policy adequate to cope with the rapid convergence of information and telecommunications technologies?

6. Group VI - Public Planning for Education in the "Information Society"

- Is there a need for better coordination and monitoring of various federally-supported educational technology programs?
- To what extent should the Federal/State Governments strive for the standardization of the components of information technology?
- Should State-level planning and support of information technology in education be increased?
- How might the use of local networks based on information technology be encouraged? In what ways could such networks be used to promote educational objectives?
- How can community planning facilitate the coordinated use of information technology in schools, libraries, workplaces, and homes?
- How might information technology be effectively employed in community "learning resource centers"?
- Should more attention be given to security and privacy when considering the use of networks and data bases in educational environments and applications?

C. Potential Methods of Fostering Legislative Initiatives

Congress, during the past decade, has begun to perceive the many ramifications of applying advanced information tools and techniques to the problems of government and society. Within the realm of education, the utilization of information technology has included computer-assisted instruction, expanded curricula focussing on the role of such technology in addressing social and community problems, and using innovative support systems for improved administration of academic programs. As the Nation enters the 1980 decade, cognizant committees within Congress have determined to review the present state-of-the-art of educational technology and to identify those initiatives that could result in improved handling of information (e.g., scientific and technical) and in more responsive educational institutions and offerings. These initiatives, whether taken by the Congress, designated Federal executive branch agencies and departments, or reponsible private sector entities, represent the key to the future. This array of actions is possible within the context of established congressional oversight functions and the traditional pattern of Member initiative through the introduction of new or modified legislation.

Several methods of fostering legislative initiatives that constitute specific courses of action, may be identified:

1. Introduction of new legislation - such bills may:
   - o Create a special study mechanism (e.g., commission or task force) to examine current user needs and responding systems and organizations.
   - o Require the incorporation of technology-supported management techniques for the planning, management, and evaluation of education's administration and curricula.
   - o Call for the continuing use of contractor personnel and services to augment in-house capabilities in this area.
   - o Identify roles for various public and private sector organizations having known missions and resources that are germane to information technology and education.
   - o Mandate the utilization, in specific activity areas, of information devices and man-machine techniques.
   - o Provide for the creation of a special information capability, such as a clearinghouse or network, that could acquire, store, process, and make available requisite data for diverse user communities.

2. Review of existing legislation - may occur as a result of individual Member action, or during the deliberations of the budget, authorization, or appropriations committees in regard to:
   - o Adequacy of Public Law goals and provisions, from the vantage point of proven program performance.
   - o Perceived effectiveness of present agency or department program implementation, especially as concerns cost-performance measurement (where appropriate) and hindsight assessment of initial project objectives.
   - o Possible redirection of departmental implementation and interpretation of directives, conducted through high level executive branch (OMB) action.

3. Analysis of sunset legislation - past valuable initiatives, often forgotten with the passage of time, merit review lest useful analyses of the problem are lost or existing information resources and services already in place be seriously diluted or unthinkingly removed.

4. "Jaw-boning" (persuasion) of responsible Federal executive branch departments and agencies - the varying roles within the Federal establishment (OMB, ED, NTIA, NSF) often are diminished or become minimal over time; legislative interest often reinforces the resolve to evaluate anew appropriate organizational frameworks, budgeting goals, program objectives, use of technology, and the implications of applying modern technology to the needs of user groups.

5. Utilization of legislative research and analysis capabilities - by calling upon the extensive resources of the Congressional Research Service, Office of Technology Assessment, General Accounting Office, and Congressional Budget Office (as appropriate), Congress can commission studies of varying scope and depth that then may be applied to selected congressional review or foresight activities.

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NOTES

INFORMATION TECHNOLOGY IN EDUCATION:

DEMONSTRATION PROGRAM

Sponsored by

The Subcommittee on Science, Research and Technology
Committee on Science and Technology
U.S. House of Representatives

and

The Subcommittee on Select Education
Committee on Education and Labor
U.S. House of Representatives

April 2-3, 1980

House Subcommittee on Science, Research and Technology

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Ken Kramer, Colorado
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Arlen Erdahl, Minnesota
John M. Ashbrook, Ohio (ex officio)

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INTRODUCTION

This brochure provides a brief guide to the technology demonstration segment of the "Information Technology in Education" seminar. The demonstration complements the hearings and workshop discussion groups, and is intended to convey to the Congress, workshop participants, and to the public some idea of the many roles "new" information technologies play in the educational process.

The projects exhibited are representative of both the wide variety of technological possibilities and a diversity in subject matter. All of the demonstrators selected have been, or are currently being, funded by various Federal agencies through grants or contracts.

Members of Congress and their respective committee and personal staffs, as well as the Workshop participants, are welcome to observe and interact with the various systems at their convenience from 4:00 P.M. to 9:00 P.M. on April 2, 1980, in Room 3547 of House Office Building Annex No. 2. On April 3, the public is welcome to observe and participate in the demonstrations between 10:30 A.M. and noon.

PARTICIPANTS

1. Association for Media-based Continuing Education for Engineers, Inc. (AMCEE)

   Dr. Lionel V. Baldwin, Dr. Arnold E. Seigel

2. Computer Corporation of America

   Lynn Brock, LeRoy Fundingsland, David Marx

3. Domestic Information Display System

   Curtis Fritz, Peter Cavas

4. Hazeltine Corporation

   John Volk, Jerry Moore, Linda Zingg, Rex Maddox

5. Minnesota Educational Computing Consortium (MECC)

   Helen T. Kock

6. National Captioning Center

   Jane Miller, Doris Caldwell, Stan Gerendasy

7. SUNY at Stony Brook

   Dr. Ludwig Braun

8. University of California — Irvine, Educational Technology Center

   Dr. Alfred Bork

9. University of Delaware — PLATO Project

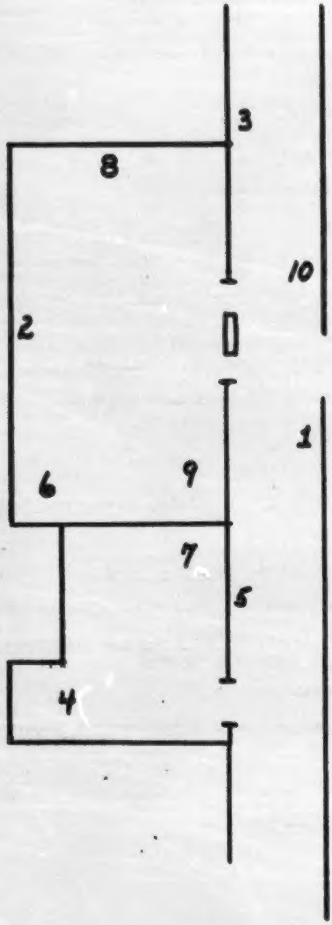
   Dr. Fred T. Hofstetter, James Wilson, Bonnie Seiler

10. Utah State University, Exceptional Child Center and Center for Instructional Product Development

    Dr. Ron Thorkildsen

(Also will demonstrate work of Nebraska ETV Network)

EXHIBITS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PARTICIPANT INFORMATION

1. **Demonstrator:** Association for Media-based Continuing Education
for Engineers, Inc. (AMCEE)
c/o Colorado State University
College of Engineering
Fort Collins, CO.

Title: "Coordinated University Programs in Engineering Via Video"

Subject Matter and Educational Implication:

Various engineering disciplines and selected applied sciences and management subjects taught through the use of videocassettes. Such a system allows for convenient, flexible, on-the-job study opportunities and credit-bearing courses to be made available to engineering students in the AMCEE consortium.

Target Audience: Engineers and technical managers in continuing and graduate education environments.

2. **Demonstrator:** Computer Corporation of America
1600 Wilson Blvd., Suite 903
Arlington, VA. 22209

Title: "Microcomputer-based Simulation in Training"

Subject Matter and Educational Implication:

Displays interactive simulations of war games, electronics trouble shooting, and models of student procedural errors. The systems to be shown are low cost, low fidelity, real-time simulations that are feasible with existing microcomputer technology and demonstrate on a broader perspective the generative nature of student errors.

Target Audience: Continuing education students.

3. **Demonstrator:** Domestic Information Display System (DIDS)
Department of Commerce
OFSPS
2001 S St., N.W.
Washington, D.C. 20009

Title: "Domestic Information Display System"

Subject Matter and Educational Implication:

Provides interactive colorgraphic presentations of statistical data that could be used as teaching tools for such subjects as statistics, political science, geography, urban/rural planning, computer sciences, and social sciences. Theories and relationships between data can be formulated and reviewed by students using such a system.

Target Audience: Government policy analysts and decisionmakers (potential for higher education students and education managers).

4. **Demonstrator:** Hazeltine Corporation
7680 Old Springhouse Road
McLean, VA. 22102

Title: "TICCIT Computer-based Training"

Subject Matter and Educational Implication:

Designed to be a criterion-referenced, self-paced instructional tool to provide basic skills in math, grammar, and reading for junior college and university-level students and operations or maintenance instruction for military applications.

Target Audience: Remedial students in higher education and military aviation personnel.

5. **Demonstrator:** Minnesota Educational Computing Consortium (MECC)
2520 Broadway Drive
St. Paul, MN. 55113

Title: "Microcomputers as Instructional Aids"

Subject Matter and Educational Implication:

Focuses on computer applications for elementary and secondary students where the computer is an instructional tool used by teachers in a classroom setting or individual students working independently with the computer. Simulations, tutorial exercises, drill-and-practice lessons, and data retrieval on such topics as language arts, elementary science, music theory, art, alegbra, social studies, and driver education will be shown.

Target Audience: Elementary, secondary, and higher education students.

6. **Demonstrator:** National Captioning Center
5203 Leesburg Pike
Falls Church, VA. 22041

Title: "Closed-captioned Television"

Subject Matter and Educational Implication:

Presents a working model of closed-captioning of television programming that is designed to benefit hearing-impaired persons. Such a system also can be used to aid children with learning disabilities.

Target Audience: Hearing-impaired persons and children with learning disabilities.

7. **Demonstrator:** SUNY at Stony Brook
College of Engineering
Stony Brook, N.Y. 11794

Title: "Microcomputers and Learning Environments"

Subject Matter and Educational Implication:

Presents such programs as simulations, drill-and-practices, and games in mathematics, science, language arts, and music. In addition, a new communications device for the neuromuscularly handicapped, that can interact with computers and other segments of the person's environment, will be demonstrated. Such a microcomputer-based learning experience takes advantage of the discovery mode of learning, promotes computer-based learning over conventional teaching methods, and presents educational lessons and concepts in a new and creative way.

Target Audience: Kindergarten through higher education.

8. **Demonstrator:** University of California — Irvine
Educational Technology Center
Irvine, CA. 92717

Subject Matter and Educational Implication:

Primary emphasis on scientific literacy, physics, and statistics taught through the use of microcomputers. Major advantages to such a system are (1) the student is in an interactive learning environment and (2) the learning experience is individualized to each participating student.

9. **Demonstrator:** University of Delaware
PLATO Project
Newark, DE. 19711

Title: "Applications of a PLATO Computer-based Educational System"

Subject Matter and Educational Implication:

Demonstrates varied topics with an emphasis on physical and social sciences, arts and humanities, health applications, and basic skills. Plato provides a highly flexible learning system with considerable human engineering factors, graphic displays, and interactive capabilities designed into the learning process.

Target Audience: Kindergarten through higher education.

10. **Demonstrator:** Utah State University
Exceptional Child Center and
Center for Instructional Product Development
Logan, UT. 84322

Title: "Microcomputer/Videodisc for Interactive CAI for the Mentally Handicapped"

Subject Matter and Educational Implication:

Presents computer-assisted instruction of various language arts and reading programs through the use of videodisc technology. This type of teaching method departs from the traditional CAI learning programs since presentations are made in non-written formats, thus benefiting non-readers. The Nebraska ETV Network videodiscs explore the limits to which interactive videodiscs can be used in individual instruction (Spanish pronunciation at the secondary level) and group instruction (basic tumbling skills at the elementary level).

Target Audience: Mentally handicapped and non-readers of all ages.

ACKNOWLEDGEMENTS

The Subcommittees wish to thank each of the demonstrators for their enthusiastic involvement and participation at their own expense in this segment of the "Information Technology in Education" seminar. In addition, the Subcommittees and demonstrators appreciate the cooperation of the following organizations in providing necessary equipment and services for the demonstration program:

Defense Advanced Research Projects Agency
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College Park, Maryland

Division of Educational Technology
U.S. Department of Health, Education, and Welfare

House Information Systems
Committee on House Administration
U.S. House of Representatives

Tektronix Inc.
Rockville, Maryland

Terak Corporation
Scottsdale, Arizona

TRANSPORTATION TO DEMONSTRATIONS

A special shuttle bus will take participants and congressional staff from the Rayburn House Office Building (South Capitol St. entrance) to the House Office Building Annex No. 2 (2d or 3d Sts. and D St. S.W.) every half hour beginning at 5:15 P.M. The last departure from House Office Building Annex No. 2 will be at 8:00 P.M.

Metro Subway is available between 1st and C St. S.E. (Capitol South) and 3d and D St. S.W. (Federal Center S.W.) during the entire demonstration period.

INFORMATION TECHNOLOGY IN EDUCATION:

PARTICIPANTS OF WORKSHOP DISCUSSION GROUPS

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Committee on Science and Technology
U.S. House of Representatives

and

The Subcommittee on Select Education
Committee on Education and Labor
U.S. House of Representatives

April 2-3, 1980

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